6700 Safety & Health
August 2000
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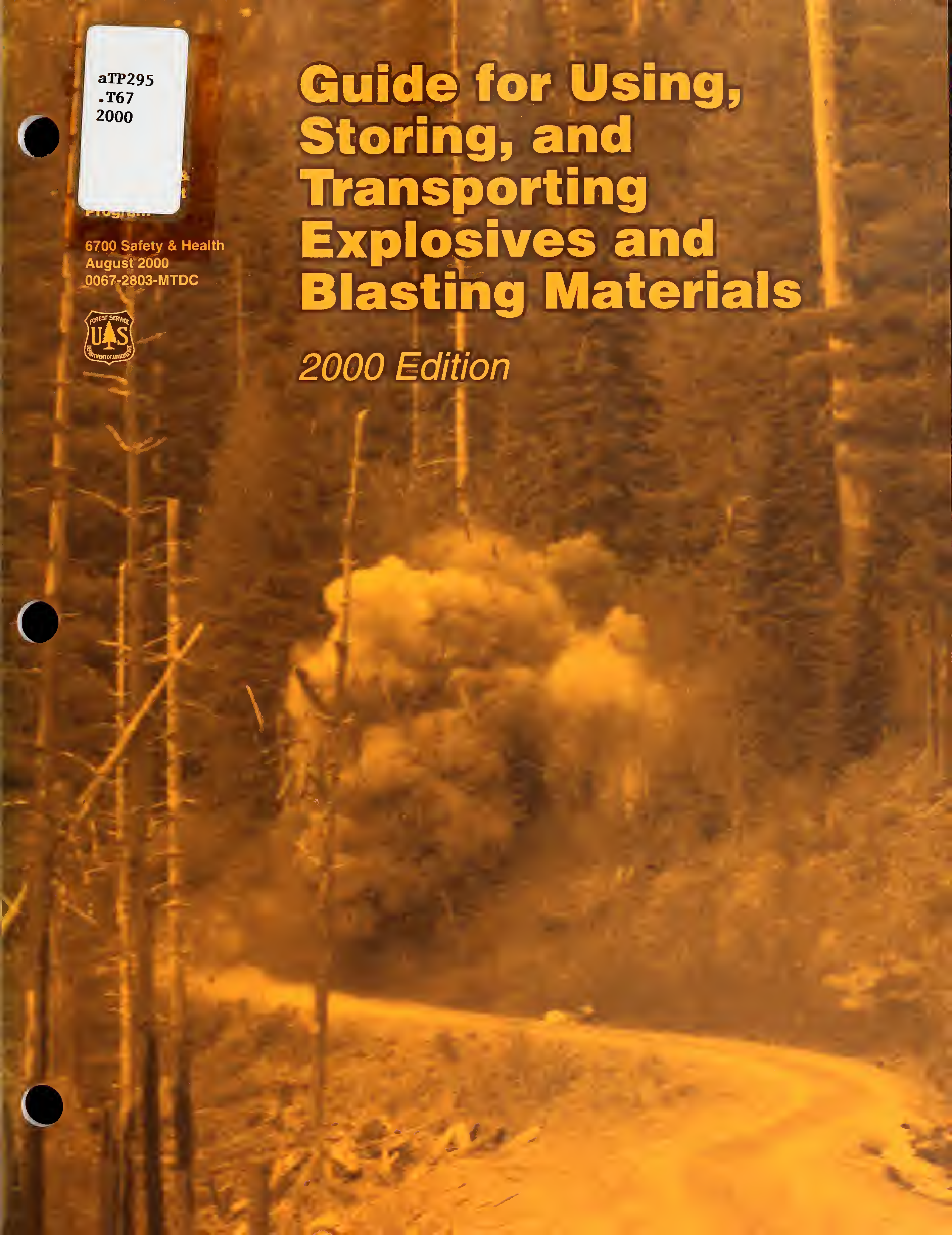
Guide for Using, Storing, and Transporting Explosives and Blasting Materials

2000 Edition



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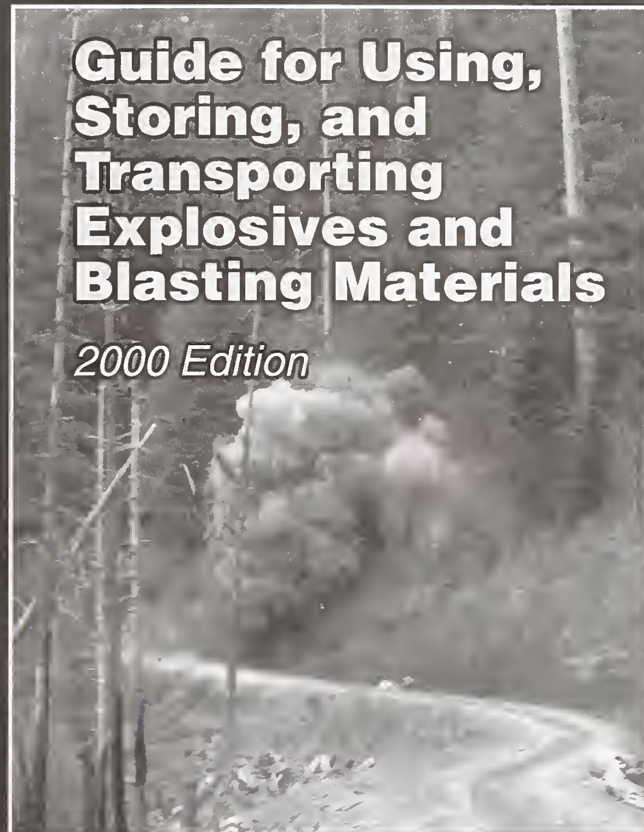


Guide for Using, Storing, and Transporting Explosives and Blasting Materials

2000 Edition

Jim Tour
Project Leader

USDA Forest Service
Technology & Development Program
Missoula, Montana

7E72H44—Revised Blaster's Guide

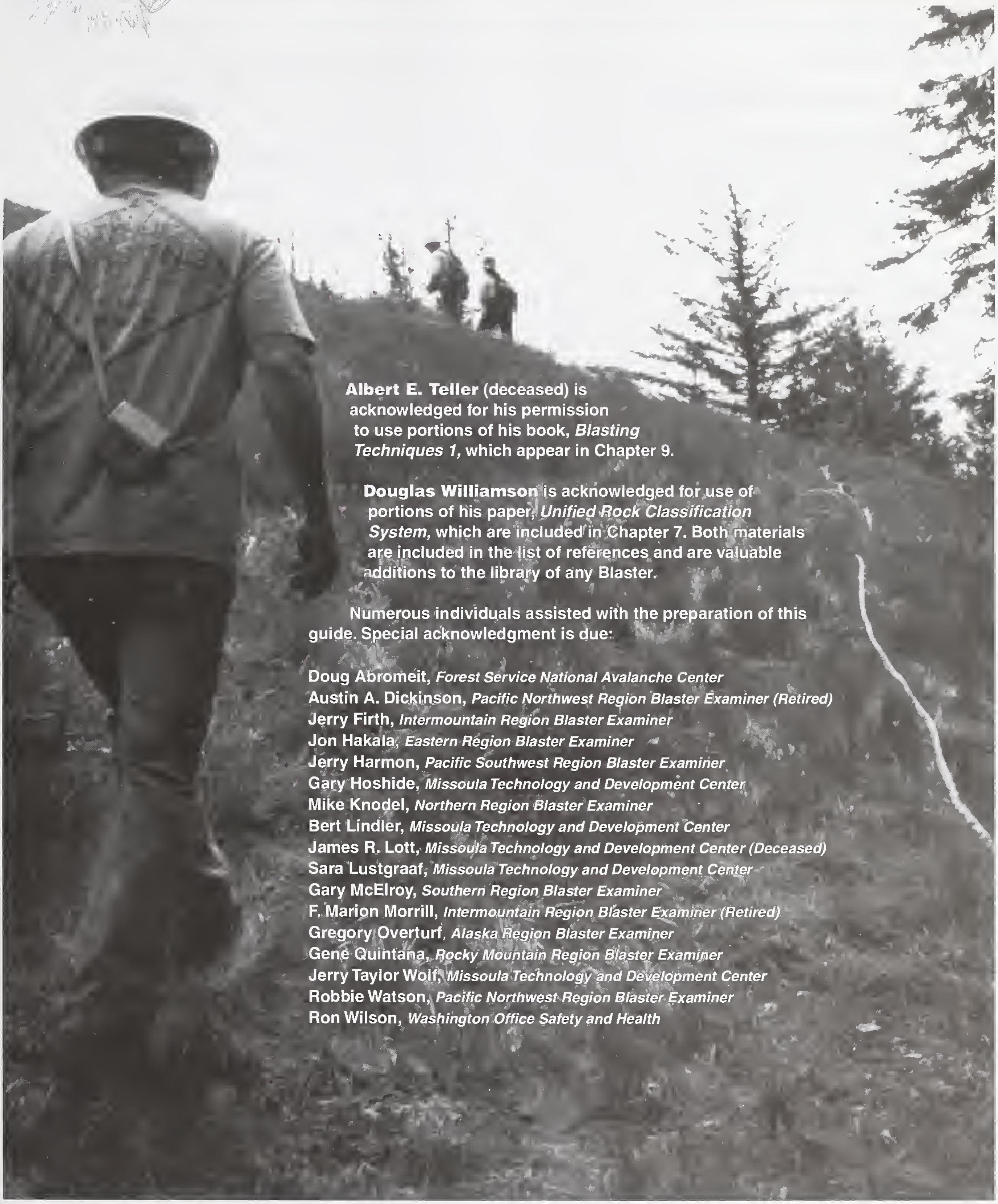
August 2000

Preface

This guide for Forest Service Blasters and Blaster Examiners presents minimum requirements for using, storing, and transporting explosives and blasting materials. It consolidates information needed to conduct normal Forest Service operations. The guide is not intended to be all-inclusive. Forest Service Blasters will need to refer to supporting documents cited in this guide.

This information was gathered from industry handbooks, the Institute of Makers of Explosives publications, Federal regulations, the *International Society of Explosives Engineers Blasters' Handbook* (revised 1998), and the Forest Service *Guide for Using, Storing, and Transporting Explosives and Blasting Materials* published (April 1992), and other sources.

Acknowledgments



Albert E. Teller (deceased) is acknowledged for his permission to use portions of his book, *Blasting Techniques 1,* which appear in Chapter 9.

Douglas Williamson is acknowledged for use of portions of his paper, *Unified Rock Classification System,* which are included in Chapter 7. Both materials are included in the list of references and are valuable additions to the library of any Blaster.

Numerous individuals assisted with the preparation of this guide. Special acknowledgment is due:

Doug Abromeit, *Forest Service National Avalanche Center*
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Gene Quintana, *Rocky Mountain Region Blaster Examiner*
Jerry Taylor Wolf, *Missoula Technology and Development Center*
Robbie Watson, *Pacific Northwest Region Blaster Examiner*
Ron Wilson, *Washington Office Safety and Health*

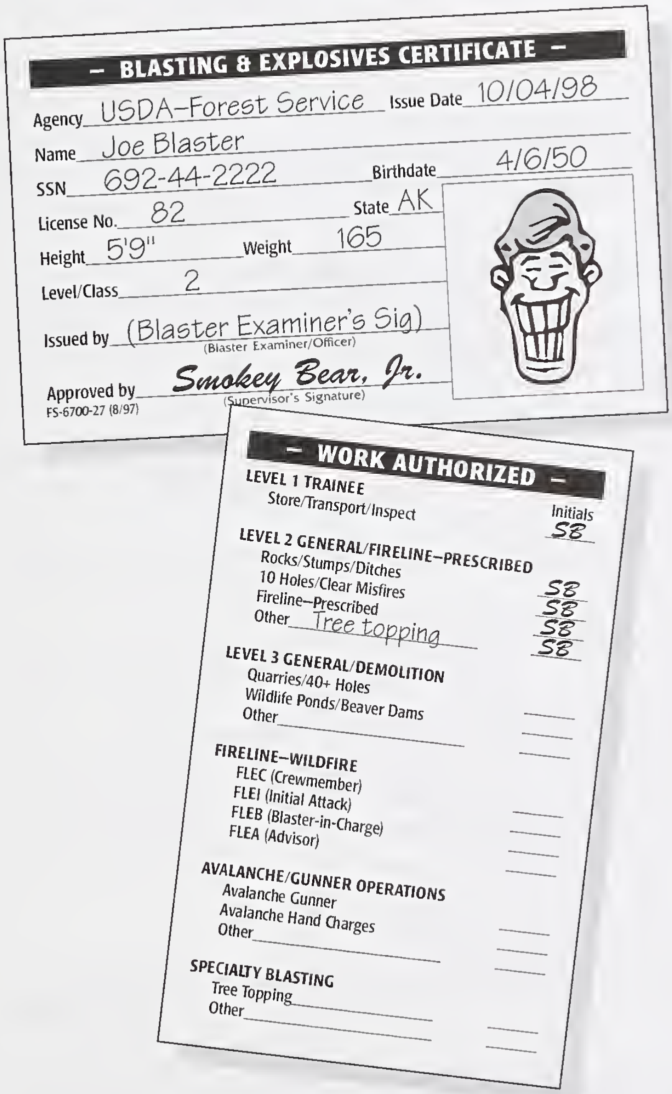
Contents

Chapter 1—General Requirements

1.1 General

1.1.1 General Requirements

All force-account blasting operations and activities including transportation, use, mixing of component explosives, storage, magazine inspection, and disposal shall be conducted under the direct supervision of a qualified Blaster who holds a current Forest Service Blaster's Certificate, FS-6700-27 (Figure 1.1).


– BLASTING & EXPLOSIVES CERTIFICATE –

Agency USDA-Forest Service Issue Date 10/04/98
Name Joe Blaster
SSN 692-44-2222 Birthdate 4/6/50
License No. 82 State AK
Height 5'9" Weight 165
Level/Class 2
Issued by (Blaster Examiner's Sig) (Blaster Examiner/Officer)
Approved by Smokey Bear, Jr. (Supervisor's Signature)
FS-6700-27 (8/97)

– WORK AUTHORIZED –

LEVEL 1 TRAINEE — Initials
Store/Transport/Inspect SB

LEVEL 2 GENERAL/FIRELINE–PRESCRIBED
Rocks/Stumps/Ditches SB
10 Holes/Clear Misfires SB
Fireline–Prescribed SB
Other Tree topping SB

LEVEL 3 GENERAL/DEMOLITION
Quarries/40+ Holes
Wildlife Ponds/Beaver Dams
Other

FIRELINE–WILDFIRE
FLEC (Crewmember)
FLEI (Initial Attack)
FLEB (Blaster-in-Charge)
FLEA (Advisor)

AVALANCHE/GUNNER OPERATIONS
Avalanche Gunner
Avalanche Hand Charges
Other

SPECIALTY BLASTING
Tree Topping
Other

Figure 1.1—A Blaster's Certificate is required.

The certificate shall specify the type of blasting qualifications, such as Level 1 Trainee, Level 2 General/Fireline-Wildfire, and Level 3 Specialty Blasting. See Forest Service Manual (FSM) 6745 for the requirements for training and certifying Blasters. When two or more Blasters are working together, one certified Blaster shall be designated Blaster-in-Charge, either by the supervisor or by the Blasters themselves.

Conduct all blasting operations and activities in accordance with the policies in FSM 6745.03 and 7103.5 and the requirements in the following:

- Warnings and instructions adopted by the Institute of Makers of Explosives (IME), that are contained in every box of explosives and blasting caps.

- Federal, State, and local laws and regulations.

Use the most stringent regulation when regulations differ.

Contact residents in or near blasting areas well in advance of (at least 24 hours before) actual blasting. Post guards and signs and verbally warn others of blasting operations. A seasonal or continuing notice is adequate for recurring work.

When blasting in the vicinity of oil, gas, electric, fire-alarm, telecommunication, and steam utilities, notify representatives of such utilities at least 24 hours in advance of blasting. Contacting Underground Service Alert (USA) in your area can generally provide notification to affected utilities. Representatives of USA will give you specific instructions for marking the location of blasting operations and will inform you of the utilities they will notify (Figure 1.2). You will need to contact other utilities that are not subscribers to USA directly, specifying the location and intended time of blasting. Confirm verbal notices in writing. For recurring work in a relatively confined area, written notice before the period or season is adequate. In an emergency, the Regional Blaster Examiner may waive the time limit.

When blasting in congested areas or near railways, highways, or structures that may be damaged, take special precautions in the loading, delaying, and initiation of explosives. Confine each blast with mats or other methods to control flyrock, airblasts, and ground vibration. If necessary, obtain assistance from the Regional Blaster Examiner or other qualified persons.

Prohibit smoking, firearms, matches, open-flame lamps, and other fires, flames, heat-producing devices, or sparks within 50 feet of explosives magazines and while explosives are being handled, transported, or used.

USA NORTH TICKET FORMAT
IN CA & NV CALL 1-800-227-2600
CALL BEFORE YOU DIG

PHONE #: (   ) ______-________ EXT: _____ ARE YOU DIGGING IN CA OR NV: ________

BEGIN DATE: ____________ (2 WORKING DAYS NOTICE REQUIRED) BEGIN TIME: ____________

YOUR NAME: ______________________________

YOUR COMPANY'S NAME: ______________________________

YOUR COMPANY'S MAILING ADDRESS: ______________________________

CITY: ______________ STATE: ______ ZIP: __________ FAX #: (   ) ______-________

WHO IS THE WORK BEING DONE FOR: ______________________________

AS REQUIRED BY LAW HAVE YOU OUTLINED YOUR WORK AREA WITH WHITE PAINT: ______

WORK PERMIT (CITY, CNTY, OR ST): ______________ # ______________

FOREMAN OF THE JOB: ______________________________

NATURE OF WORK: (BLASTING, BORING, DRILLING, GRADING, TRENCHING, TUNNELING, ETC.)

____

LOCATION: PROVIDE THE COUNTY, PLACE AND ADDRESS OR DESCRIPTION OF WHERE YOU WILL BE DIGGING (INCLUDE NEAREST INTERSECTING STREET, SIDE OF STREET, FOOTAGES, AND OTHER TIE IN MEASUREMENTS).

COUNTY: ______________ PLACE: ______________

____

____

____

____

TICKET #: ____________ DATE CALLED: ____________ EXPIRATION DATE: ____________

CALLING HOURS ARE 6:00 A.M. - 7:00 P.M. MONDAY THROUGH FRIDAY EXCLUDING WEEKENDS AND HOLIDAYS LISTED BELOW.

A TWO WORKING DAY NOTICE IS REQUIRED ON ALL USAN TICKETS, INCLUDING RENEWALS AND EXTENSIONS. EACH USAN TICKET IS ACTIVE FOR 14 CALENDAR DAYS FROM THE DATE IT IS CALLED IN. THE EXCAVATOR IS REQUIRED TO OUTLINE THE EXCAVATION IN WHITE PAINT (USAN RECOMMENDS CHALK BASE PAINT TO MINIMIZE STREET GRAFFITI). THE USAN CENTER IS CLOSED: NEW YEAR'S, PRESIDENTS' DAY, MEMORIAL DAY, INDEPENDENCE DAY, LABOR DAY, THANKSGIVING DAY, DAY AFTER THANKSGIVING, AND CHRISTMAS.

UNDERGROUND SERVICE ALERT OF NORTHERN CALIFORNIA AND NEVADA

Figure 1.2—The *Underground Service Alert (USA) North Ticket Format* form must be completed when blasting near utilities.

Do not allow anyone to handle explosives while under the influence of alcoholic beverages or drugs, or when using prescription drugs that impair judgment or performance.

Never abandon explosives, ammunition, blasting agents, or blasting materials.

Never fight a fire that is in imminent danger of contacting explosives. Evacuate all emergency-service personnel, bystanders, and residents from the area and prevent reentry while danger exists. Guard all access routes to the fire area to prevent inadvertent access.

Insofar as possible, conduct blasting operations between sunup and sundown and during periods of clear visibility. If artificial light is needed, use approved battery-powered electric safety flashlights or electric safety lanterns. Flashlights or lanterns shall have nonconductive cases and shall not touch explosives.

Use exploding bridgewire (EBW) detonators, nonelectric systems, or combinations of the two, to initiate charges. These are the detonation systems of choice for all Forest Service blasting operations and activities, unless their use is not appropriate for a particular blasting application.

Never carry primers or loose detonators in your pockets or in the same container with explosives.

Never store or transport detonating cord in the same container with detonators.

Use only explosives or explosive materials on the list of approved explosives and blasting materials.

Ensure that a Material Safety Data Sheet (MSDS) for explosives and blasting materials is available at the workplace or job site, and that a Job Hazard Analysis (JHA) in Figure 1.3, is conducted in accordance with the Forest Service Handbook 6709.11.

1.1.2 Aircraft, Airspace, and Blasting Operations

Before conducting blasting operations, the Blaster-in-Charge is responsible for conducting a thorough evaluation of all possible hazards and documenting them in a JHA. Two hazards that need to be addressed are the danger posed by aircraft on electric blasting circuits and the danger posed by blasting operations on aircraft (flyrock, airblast, and other hazards). Some military aircraft produce enough radio-frequency output (wattage) to detonate electric blasting caps that are shunted in a circuit. The shock waves and noise of low-flying military aircraft can cause extreme stress on personnel who are loading holes and wiring circuits. On the other hand, flyrock and airblast can cause significant damage to low-flying aircraft.

The following standard operating procedures are recommended for all blasting operations, especially those in locations where aircraft fly frequently.

* Contact land management agencies (Forest Service, Bureau of Land Management, Park Service, or State and County municipalities) to determine if military training corridors or flight paths are a concern in the area where blasting will be conducted.

* Analyze the blasting operation and determine if flyrock or airblast will be of concern to low-flying aircraft. Consider controlling flyrock and airblast by using blast mats or overfill such as sand. If flyrock or airblast will be cast above the tree canopy in areas where aircraft will be flying, the Federal Aviation Administration (FAA) must be contacted to close the airspace.

* Determine if radio-frequency initiation will be a problem. The military uses high-wattage output devices. Tables are not available to establish safe distances from electric initiators for such devices. When in doubt, consider using nonelectric initiation systems or systems that are not susceptible to detonation from stray current (such as exploding bridgewire detonators).

* Just before initiating a blast, listen for incoming aircraft. Do not detonate a shot when aircraft are in the vicinity. Wait for the aircraft to leave the area before firing the shot.

Air space closure can be obtained by contacting the dispatch office in land-management-agency units. To obtain airspace closure, the Blaster-in-Charge must provide the latitude, longitude, and time of day for the blast. If several shots are planned, consider alternatives such as blast mats or overfill to control flyrock and airblast. It may be necessary to maintain continual contact with dispatch or with aircraft in the area to tell them of the time of blasting operations.

JOB HAZARD ANALYSIS (Instructions on Reverse-Ref FSH 6709.12)	1. Primary Job/Pr Blasting Projects	2. Location Specific Field Location	3. Unit Your Field Uni
	4. Name of Analys Jim Tour	5. Job Title of Analyst Blaster in Charge	6. Date Prepare

7. Tasks/Procedures	8.Hazards	9. Abatement Actions ENGINEERING CONTROLS * SUBSTITUTION * ADMINISTRATIVE CONTROLS * PPE
Planning and Pre-Work	* Remote locations. * Lack of Emergency Evacuation plans, Blast plans, and safety briefings.	* Size up the area ahead of time. * Develop emergency evacuation plans that consider communications, helispots, first aid, and who does what. * Conduct safety and health sessions, establish personal protection equipment needed, and have all plans before going to the field. * Follow up and modify plans as necessary. Implement LCES if needed.
Storage and Transport of Explosives	* Air space closure. * Lack of handbooks or reference guides.	* Consider air space closure in military training corridors (dispatch). * Have and reference the Forest Service "Guide for Using, Storing, and Transporting Explosives and Blasting materials". * Select appropriate sized first aid kit/body fluid barriers kit for crew size.
Drilling (small portable drill) and outdoor exposure (all operations).	* Exposure to dust. * Drilling Into foot. * Back injury (lift) * Exposure to sun and insect bites.	* Wear dust masks when drilling. *Wear 8 inch leather laced field boots that protect the feet from the drill bit. Lift the drill with legs, not the back. Use a back brace (optional). * On hot sunny days, wear sun screen and if needed, insect repellent, otherwise wear long shirts, pants, and leather gloves. * Wear UV protective sunglasses.
Drilling (large shots such as quarries) Note: Fill out a separate JHA for the drilling operation.	* Drilling into Explosives.	* Never drill into existing holes that have been loaded. * Never drill into bootlegs.
Loading holes with explosives	* Accidental detonation.	*Do not tamp primers. * Follow the "ALWAYS and NEVER" instructions contained in every box of explosives and caps. Follow manufacturers instructions.
Guarding the shot	* Inadequate guarding (leading to entry by unauthorized people)	*Post appropriate signs and guards around the perimeter of each shot. * Post appropriate (large construction shots and quarries).
Firing the shot (Blaster-in-Charge or B-I-C)	Premature firing & misfires.	* B-I-C controls the blasting machine. * Do not mishandle or tamp caps or primers. * Use EBW's or Nonel around sources of electromagnetic radiation (radios, radar, transmission towers, etc) or extraneous electricity (equipment). * Shut down when lighting approaches. * Avoid using cap-and-fuse. * Double check that all holes are tied into shot. *Wear hard hat and eye protection.
The blast (detonation)	* Flyrock and flying debris. * Loose rock & debris from hillsides. *Tree tops and limbs. *Shock wave. * Bee/Hornet stings.	*Size up the blast area and safe zones before the shot. Look up and around for dead loose limbs, tree tops, and for debris and rocks that might jar loose. * Take adequate cover - stay back at least 500 feet from the blast - further on the larger shots. * Always face the shot watching for flyrock and debris. *Wear hearing protection if shock wave is 85 dBA and above. * Watch for nests around the shot. Have appropriate first aid kit.
Post blast entry and inspection	* Fumes and flying debris.	* Do not return to the blast site until: the dust and debris settles, and the fumes disburse (see ventilating).
Digging (heavy equipment) Note: Fill out a separate JHA for running and operating heavy equipment.	*Digging into explosives and detonating.	* Ensure that all explosives detonated (post blast Inspection). Use insensitive explosives such as water gels, emulsions, or ANFO.
Fire caused by the blast or Explosives on fire	*Wildfire and fires caused by blasting	* Fire tools (buckets, shovels, axes) will be available at remote blast blast sites. Fire extinguishers at other sites. Never try to put out explosives that are on fire. Assume they will detonate at anytime.
Ventilating	* Toxic fumes in mines and ditches.	* Allow sufficient time for fumes to vent. Use blowers. Use Monitors. Use SCBA in mines where determined by monitoring.

10. Line Officer Signature	11. Title	12. Date

Previous edition is obsolete

(over)

Figure 1.3—Completion of the Job Hazard Analysis form is required for each blasting project.

1.2 Inspection

1.2.1 Magazine Condition

Explosives magazines shall be thoroughly inspected annually for the physical condition of the magazine and the condition of any explosive materials contained within them. Use the Explosives Storage Magazine Condition Report (Figure 1.4) to document inspections.

1.2.2 Explosive Materials in Storage

Any person storing explosive materials shall inspect the magazine at least every 7 days. This inspection need not be an inventory, but must be sufficient to determine whether there has been unauthorized entry or attempted entry into the magazine. Notify the nearest Regional Office of the Bureau of Alcohol, Tobacco, and Firearms (BATF) and appropriate State offices within 24 hours of any loss, theft, or unauthorized entry into a magazine. Complete form ATF F 4712 (5400.5) shown in Figure 1.5.

1.3 Records

Maintain a record of changes in inventory and of inspections at each magazine; file a duplicate record at unit headquarters. The record must show the dates of inspections and the inspector's signature, the dates explosives are entered into or removed from storage, and the signature or initials of the person entering or removing explosives. The record also must show types of explosives, quantities, and manufacturer. Figure 1.6 shows a properly filled out Inspection and Inventory Record. Figure 1.7 is a blank form that can be duplicated. Keep records of explosives purchases for at least 5 years.

Maintain a Blasting Report (Figure 1.8), showing the date and time of each blast and the amount and type of explosives used. Maintain a base-operations plan that includes a Hazardous Materials Emergency Response Plan.

MAGAZINE CONDITION
Explosives Storage Magazine Condition Report

Inspect condition of magazine and explosives annually in accordance with the following report format.

Inspector:

Magazine location: Township________ Range__________ Section__________ County State

National Forest:

Magazine name or number:

Date:

Name and title of designated individual responsible for magazine:

Other personnel, if any, designated secondary responsibility:

Do these personnel hold current Blaster's Certificate authorizing handling, transportation, and storage? ____*Yes* ____*No*

Is this a Forest Service magazine? ____*Yes* ____*No*

MAGAZINE SITE

Conformance with American Table of Distances:

- Is maximum storage stenciled or painted on inside wall of magazine? ____Yes ____No
- Maximum quantity of explosives authorized for storage in magazine _______ lbs.
- Quantity stored _______ lbs.
- Barricaded? ____Yes ____No
- Distance to nearest inhabited building, dwelling _______ feet
- Distance to nearest public road _______ feet
- Distance to nearest ski lift, downhill ski run, or other public facility _______ feet.
- Site conforms to standards? ____Yes ____No

Is there utilization of natural barriers? Describe:

____

____

____

____

____

Drainage of terrain near magazine, (slope, direction of flow, soil, etc.). Describe:

____

____

____

____

Exposure to Sun (south slope, north slope, shaded by trees, covered by snowbank, etc.). Describe:

____

____

____

____

Accessibility to other than authorized personnel, i.e. exposed to careless discharge of firearms, vandalisms, etc. Describe:

____

____

____

____

Figure 1.4—The *Explosives Storage Magazine Condition Report* must be completed annually *(continued on next pages)*.

CONSTRUCTION OF MAGAZINE

Type of Structure (check one)

____Reinforced concrete ____Brick or masonary
____Frame ____Exposed wood
____Metal-sheathed outside ____Other (describe):

____

- Is structure bullet proof? ____Yes ____No
- Rodent proof? ____Yes ____No

Flooring (check one)

____Wood: Are nails exposed? ____Yes ____No
____Earth
____Concrete: Are duckboards, pallets, or rubber mats concrete? ____Yes ____No
Are there any spark-producing hazards on the floor? ____Yes ____No

If yes, describe: ______________________________

____

Ventilation

- Is flooring set back 5 inches from wall? ____Yes ____No
- If concrete floor, are duckboards or pallets provided? ____Yes ____No
- If yes, how are the vents screened? ______________________________

____

- What is the condition of screening? ______________________________

____

- What type of roof vent is provided? ______________________________

____

- Are vents installed with an indirect flow of air? ____Yes ____No
- Is the air venting adequate for this magazine? ____Yes ____No

Lightning and Static Protection

- Is there a lightning rod system? ____Yes ____No
- If yes, describe: (rod, cables, ground, and condition; corroded? broken?) ______________________________

____

____

STORAGE METHOD & CONDITION OF EXPLOSIVES MAGAZINE

Storage

- Explosives at least 5 inches from walls? ____Yes ____No
- Explosives cases stacked top-side up? ____Yes ____No
- Is there sufficient room between stacks to permit circulation of air? ____Yes ____No
- Are caps or made up primers stored in explosives magazine? ____Yes ____No
- Are explosives stacked so oldest stock may be used first? ____Yes ____No
- Are open or partially used cases, stacked separately from full ones? ____Yes ____No
- Are stacks separated according to type and grade? ____Yes ____No

Condition of Explosives

- Are cases damp? ____Yes ____No
- Are explosives damp inside cases? ____Yes ____No
- Are any cases broken, rodent gnawed, or in any way damaged? ____Yes ____No
- Check the signs of deterioration, if any, of the following items:
  - Explosives are darkening in color? ____Yes ____No
  - Explosives soft and mushy in texture? ____Yes ____No
  - There are fumes in the magazine? ____Yes ____No
  - Cases are stained? ____Yes ____No
  - Is there any indication of leakage in the explosives? ____Yes ____No
- If the answer to any of the above is yes, describe:

____

____

Figure 1.4—*Continued.*

STORAGE METHOD & CONDITION OF EXPLOSIVES MAGAZINE, *continued*

- Does any explosive in magazine appear to be deteriorated to the point where it is dangerous to handle and would require disposal by military EOD teams? ____Yes ____No
- If yes, describe in full: ________________________________

____

SPECIAL NOTE—
If the above described condition exists, close magazine and immediately notify District Ranger, Forest Engineer, Regional Forester, and Regional Blaster Examiner.

Detonating Cord

- Detonating cord stored in magazine is in moisture- and rodent-proof container? ____Yes ____No
- Is it damp, rodent gnawed, or the protective covering damaged in any way? ____Yes ____No
- If yes, describe: ________________________________

____

Detonator (Cap) Magazine

- Cap magazine is ________feet from the explosives magazine.
- Are caps in rodent-proof containers if necessary? ____Yes ____No
- Is the magazine rodent proof? ____Yes ____No
- Are the caps damp? ____Yes ____No
- Are caps stored in such a manner as to be exposed to any hazard from friction, static, or falling objects? ____Yes ____No
- If yes, describe: ________________________________

____

- Do caps show corrosion, cracking of insulation on leg wires, or other signs of deterioration? ____Yes ____No
- If yes, describe: ________________________________

____

- Other blasting materials besides caps and fuses are stored in cap magazine. ____Yes ____No
- If yes, describe: ________________________________

____

____

CLEANLINESS OF MAGAZINE

- The floor of the magazine is swept clean? ____Yes ____No
- If no, describe:________________________________

____

- Is the floor of the magazine stained from leaky explosives? ____Yes ____No
- If yes, describe:________________________________

____

- Are there empty explosives containers in the magazine? ____Yes ____No
- If yes, describe:________________________________

____

- Is the general appearance of the magazine clean, neat, and orderly? ____Yes ____No
- Remarks:________________________________

____

____

____

____

Figure 1.4—*Continued.*

FIRE PREVENTION

- Is brush cleared around outside of the magazine for at least 50 feet? ____Yes ____No
- The ground around the magazine for ________ feet is cleared to mineral soil.
- Are there any serious fire hazards in the immediate vicinity of the magazine? ____Yes ____No

SIGNING AND MARKING OF MAGAZINE

- Do the magazine markings conform to Forest Service safety code? ____Yes ____No
- If no, describe:____________________

INVENTORY RECORDS

- Is an explosives inventory record kept in the magazine? ____Yes ____No
- If yes, describe form (or submit with inspection report):
____
- Where is a second copy kept?____________________
- Are the inventory records neat, legible, and kept up to date? ____Yes ____No
- Is any provision made to date mark cases upon arrival at the magazine so the oldest stock may be identified? ____Yes ____No
- If yes, describe:____________________

MISCELLANEOUS

- Is the magazine securely locked with at least two special high-security locks? ____Yes ____No
- Special locks meet BATF regulations? ____Yes ____No
- Are the keys strictly controlled? ____Yes ____No
- Is any explosive material not belonging to the Forest Service stored here? ____Yes ____No
- If yes, describe:____________________
- Is anything—particularly iron or spark-producing items other than explosives or caps—stored in the explosives or the cap magazines? ____Yes ____No

Inspection Rating

☐ **Satisfactory**

☐ **Needs corrections**

Inspector's remarks and recommendations:
(If more room is needed, use additional sheet of paper.)

Figure 1.4—*Continued.*

Form Approved: OMB No. 1512-0185 (7/31/84)

DEPARTMENT OF THE TREASURY – BUREAU OF ALCOHOL, TOBACCO AND FIREARMS

REPORT OF THEFT OR LOSS – EXPLOSIVE MATERIALS

DATE

Note: Section 842(k), 18 U.S.C. Chapter 40 provides that "It shall be unlawful for any person who has knowledge of the theft or loss of any explosive materials from his stock to fail to report such theft or loss within twenty-four hours of discovery thereof to the Secretary and to appropriate local authorities." Theft or loss must be reported immediately by telephone to the nearest ATF office, listed on reverse, and a report must be made on this form within 24 hours to the same office (27 CFR 181.30). It is suggested that a copy of this report be retained by the person making the report. Attach additional sheets or invoices, if necessary, to provide the required information. Each item should be completed as applicable to the best of your ability.

1. NAME, ADDRESS AND TELEPHONE NUMBER OF PERSON MAKING REPORT *(Include corporate or business name, if applicable)*

2. LOCATION OF THEFT OR LOSS *(If different from item 1)*

3. THEFT OR LOSS	DATE	TIME
a. DISCOVERED		
b. OCCURRED *(Show approximate if exact not known)*		
c. REPORTED TO ATF BY TELEPHONE		
d. REPORTED TO LOCAL AUTHORITIES		

4. ATF OFFICE TO WHICH REPORTED BY TELEPHONE

5. NAME AND ADDRESS OF LOCAL AUTHORITY TO WHOM REPORTED

6. EXPLOSIVE MATERIALS LOST OR STOLEN *(Attach invoices or additional sheets, if necessary)*

a. MANUFACTURER OR BRAND NAME *(Include date and shift code)*	b. QUANTITY *(Pounds of Explosives, Number of Caps)*	c. TYPE AND DESCRIPTION *(Dynamite, Blasting Agents, Detonators, etc. Include for each type, size, MS delay or length of legwire, as applicable)*

7. THEFT OR LOSS OCCURRED FROM *(Check applicable box)*

☐ PERMANENT MAGAZINE ☐ PORTABLE MAGAZINE ☐ TRUCK ☐ WORK SITE ☐ OTHER *(Explain)*

8. ENTRY TO MAGAZINE MADE THROUGH *(Complete if applicable)*

☐ DOOR ☐ ROOF ☐ FLOOR ☐ FOUNDATION

☐ WALL ☐ CEILING ☐ VENTS ☐ OTHER *(Explain)*

9. NUMBER AND TYPE OF LOCKS FORCED *(Complete if applicable)*

10. OTHER INFORMATION PERTINENT TO THE THEFT OR LOSS

11. SIGNATURE AND TITLE OF PERSON MAKING REPORT

12. FEDERAL EXPLOSIVES LICENSE OR PERMIT, IF ANY

FOR ATF USE ONLY

DATE RECEIVED	TIME RECEIVED	UNIQUE IDENTIFIER

ATF F 4712 (5400.5) (11-81) PREVIOUS EDITIONS ARE OBSOLETE

Figure 1.5—Theft or loss of explosives materials must be reported.

INSPECTION AND INVENTORY RECORD

Region: Southern

Forest:

District:

Magazine:

Check one: ☑ Explosives Magazine ☐ Detonator Magazine

INVENTORY

Explosives Type: TNT — Mfr: IC

Date	Initials	Added or Removed	Running Inventory	Date Code
7/2	JT	5 Cases	5 Ca	7/1
7/30	JT	4 Cases	1 Ca	
8/5	JT	10 Ca	11 Ca	7/7

Explosives Type: — Mfr:

Date	Initials	Added or Removed	Running Inventory	Date Code

Explosives Type: FLE — Mfr: DP

Date	Initials	Added or Removed	Running Inventory	Date Code
7/8	JT	10 Ca	10 Ca	IL27
7/15	JT	1 Case	9 Ca	

SAMPLE

Explosives Type: — Mfr:

Date	Initials	Added or Removed	Running Inventory	Date Code

Explosives Type: Det Cord — Mfr: EB

Date	Initials	Added or Removed	Running Inventory	Date Code
7/10	JT	1000'	1000'	256
7/15	JT	100'	900'	

Explosives Type: — Mfr:

Date	Initials	Added or Removed	Running Inventory	Date Code

Explosives Type: — Mfr:

Date	Initials	Added or Removed	Running Inventory	Date Code

Explosives Type: — Mfr:

Date	Initials	Added or Removed	Running Inventory	Date Code

INSPECTION

If stock has been added or removed, update the Inventory section.

Date	Signature	Inspected (Check action)	Added stock	Removed stock

97-16-MTDC

Figure 1.6—The *Inspection and Inventory Record* must be kept current.

INSPECTION AND INVENTORY RECORD

Region:

Forest:

District:

Magazine:

Check one: ❑ Explosives Magazine

❑ Detonator Magazine

INVENTORY

Explosives Type | Mfr

Date	Initials	Added or Removed	Running Inventory	Date Code

Explosives Type | Mfr

Date	Initials	Added or Removed	Running Inventory	Date Code

Explosives Type | Mfr

Date	Initials	Added or Removed	Running Inventory	Date Code

Explosives Type | Mfr

Date	Initials	Added or Removed	Running Inventory	Date Code

Explosives Type | Mfr

Date	Initials	Added or Removed	Running Inventory	Date Code

Explosives Type | Mfr

Date	Initials	Added or Removed	Running Inventory	Date Code

Explosives Type | Mfr

Date	Initials	Added or Removed	Running Inventory	Date Code

Explosives Type | Mfr

Date	Initials	Added or Removed	Running Inventory	Date Code

INSPECTION

If stock has been added or removed, update the Inventory section.

Date	Signature	(Check action) Inspected	Added stock	Removed stock

97-16-MTDC

Figure 1.7—Blank *Inspection and Inventory Record* form.

BLAST REPORT

Date:	Location:	Type Rock:

Sonic Velocity:	Hole Size:	Hole Depth:	No. Holes:
Spacing:	Burden:	Stemming:	Water:

Powder Used

Brand:	Type:	Stick Size:	Calculated Cu.Yds.:

Powder Factor:	No. Lbs./Hole:	Total Lbs. Used:

Signature

Show all calculations below:

Sketch of Blast and Delay Electric Blasting Caps
Use North Arrow

Figure 1.8—The *Blast Report* form must be completed for each project.

Chapter 2—Explosives

2.1 Explosives Products

2.1.1 General

In general, explosives are chemical compounds or mixtures that have the following characteristics:

* Ignites by heat, shock, impact, friction, or a combination of these conditions.

* Decompose rapidly in a detonation when it is ignited.

* Release heat and large quantities of high-pressure gases so rapidly that the force overcomes confining forces.

* Release energy by the detonation of explosives, producing:
  - Rock fragmentation
  - Ground vibration
  - Rock displacement
  - Airblast.

The ingredients used in the manufacture of explosives include:

Explosives Bases—An explosive base is a solid or a liquid which, upon application of heat or shock, breaks down very rapidly into gaseous products, with an accompanying release of heat energy. Nitroglycerin (NG) is an example.

Combustibles—A combustible combines with excess oxygen in an explosive to achieve oxygen balance, to prevent the formation of nitrous oxides (toxic fumes) and to lower the heat of the explosion.

Oxygen Carriers—Oxygen carriers assure complete oxidation of the carbon in the explosive mixture, which inhibits the formation of carbon monoxide. The oxygen carriers assist in preventing a lowering of the explosion temperature. A lower heat of explosion means a lower energy output and thereby less efficient blasting.

Antacids—Antacids are added to an explosive compound to increase its long-term storage life, and to reduce the acidic value of the explosive base, particularly for nitroglycerin (NG).

Absorbents—Absorbents are used in dynamite to keep the explosive base from exuding or seeping out, and to keep the explosive base from settling in the bottom of the cartridge or container. Sawdust is often used as an absorbent.

Antifreeze—Antifreeze is used to lower the freezing point of the explosive.

2.1.2 Air-Gap Sensitivity

Air-gap sensitivity is a measure of an explosive's cartridge-to-cartridge sensitivity to detonation—under test conditions, expressed as the distance through air at which a primed half-cartridge (donor) will reliably detonate an unprimed half-cartridge (receptor).

2.1.3 Cap Sensitivity

Cap sensitivity is a measure of the minimum pressure, energy, or power required for initiation of a detonation. Some explosives will detonate reliably with a No. 6 or No. 8 cap (nitroglycerin-based explosives) while others will not (ammonium nitrate-fuel oil explosives).

2.1.4 Strength

Strength is usually considered to be the ability of an explosive to do useful work. This term was erroneously associated with case strength markings. Neither weight strength nor bulk strength is a good basis for choosing an explosive, but because many Blasters still use the term, a history of its use is included here.

The word *straight* was first applied to dynamites when dynamite was a mixture of nitroglycerin and inert filler, such as kieselguhr (diatomaceous earth).

Sixty-percent dynamite contained 60-percent nitroglycerin by weight and was three times as strong as 20-percent dynamite. Today's dynamites substitute active ingredients, such as sodium nitrate and carbonaceous fuel for the inert filler. This adds substantially to the energy in the explosive. Consequently, 60-percent straight dynamite, which contains 60-percent nitroglycerin by weight, is only about one-and-one-half times as strong as 20-percent dynamite, not three times as strong. The sodium nitrate and carbonaceous material in the 20-percent dynamite supply additional energy.

Two strength ratings are used for commercial dynamite. Weight strength compares explosives on weight basis and cartridge strength or bulk strength compares explosives on a volume basis.

Strengths are expressed as a percentage, with straight nitroglycerin dynamite taken as the standard for both weight and cartridge-strength ratings. For example, according to the strength rating system, 1 pound of extra dynamite with a 40-percent weight strength and 1 pound of ammonia gelatin with a 40-percent weight strength are each said to be equivalent to 1 pound of 40-percent straight dynamite. A $1\frac{1}{4}$ by 8-inch cartridge (Figure 2.1) of extra dynamite with a 30-percent cartridge strength and a $1\frac{1}{4}$ by 8-inch cartridge of semigelatin dynamite with a 30-percent cartridge-strength rating are each said to be equivalent to a $1\frac{1}{4}$ by 8-inch cartridge of 30-percent straight dynamite. By definition, an explosive's weight strength and cartridge strength are said to be equal when the specific gravity is 1.4, the density of most straight dynamites.

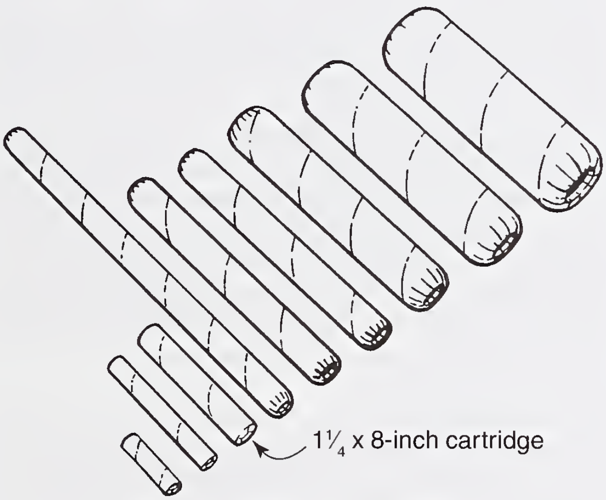


Figure 2.1—Standard cartridge sizes.

To add to the confusion, 50-percent straight dynamite and 50-percent extra dynamite produce different results in the field, primarily because of a difference in density and detonation velocity. The relation between the weight strength and cartridge strength of a given explosive depends on its density. When the specific gravity (1.4), weight, and cartridge strength (detonation velocity of 17,000 fps) of 50-percent straight nitroglycerin dynamite are compared to a 50-percent low-density (1.2) ammonia dynamite, low-velocity series (8,100 fps), they are said to be equal or do the same work (Tables 2.1, 2.2, and 2.3). Neither weight strength nor cartridge strength is a good basis for choosing an explosive. Detonation pressure, a function of detonation velocity and density, is a better indicator of an explosive's ability to perform work.

2.2 Properties of Explosives

By knowing the properties of explosives that are critical to performance, meaningful predictions can be made in blast design. These properties are detonation velocity, density, detonation pressure, water resistance, and fume class. For a given explosive these properties vary with the manufacturer and their methods of property measurement. Tables 2.1 to 2.7 provide some examples of explosives properties. Suppliers will provide this type of information on their products.

Table 2.1—Properties of straight nitroglycerin dynamite.

Weight strength (percent)	Cartridge strength (percent)	Density	Confined velocity (VOD)(fps)	Water resistance	Fume class*	Cartridge count
60	60	1.3	19,000	Good	Poor	106
50	50	1.4	17,000	Fair	Poor	104
40	40	1.4	14,000	Fair	Poor	100
30	30	1.4	11,500	Poor	Poor	100
20	20	1.4	9,000	Poor	Poor	100

Table 2.2—Properties of high-density ammonia dymamite.

Weight strength (percent)	Cartridge strength (percent)	Density	Confined velocity (VOD)(fps)	Water resistance	Fume class*	Cartridge count
60	52	1.3	12,500	Fair	Good	110
50	45	1.3	11,500	Fair	Good	110
40	35	1.3	10,500	Fair	Good	110
30	25	1.3	9,000	Fair	Good	110
20	15	1.3	8,000	Fair	Good	110

Table 2.3—Properties of low-density ammonia dynamite, low-velocity series.

Weight strength (percent)	Cartridge strength (percent)	Density	Confined velocity (VOD)(fps)	Water resistance	Fume class*	Cartridge count
65	50	1.2	8,100	Fair	Fair	120
65	45	1.1	7,800	Poor	Fair	129
65	40	1.0	7,500	Poor	Fair	135
65	35	1.0	7,200	Poor	Fair	141
65	30	0.9	6,900	Poor	Fair	153
65	25	0 .9	6,500	Poor	Fair	163
65	20	0.8	6,300	Poor	Fair	174

Table 2.4—Confined detonation velocity and borehole loading density of ANFO.[1]

Borehole diameter (inches)	Confined velocity (fps)	Loading density (lb/ft of borehole)
2	5,000 to 7,500	1.1 to 1.3
3	9,000 to 10,000	2.5 to 3.0
4	10,500 to 11,500	4.4 to 5.2
5	11,500 to 12,500	6.9 to 8.2
6	12,000 to 12,800	9.9 to 11.7
7	12,300 to 13,100	13.3 to 15.8
8	12,500 to 13,300	17.6 to 20.8
9	12,800 to 13,500	22.0 to 26.8
10	13,000 to 13,500	27.2 to 32.6
11	13,200 to 13,500	33.0 to 39.4
12	13,300 to 13,500	39.6 to 46.8

[1]Density: 0.85 to 0.95 g/cc.
Water resistance: Packaging only; do not use under wet conditions.
Shelf life: 1 year (fuel oil begins to separate after 6 months and will stain bags.)

Table 2.5—Properties of emulsions.

Product	Density g/cc	Velocity ft/sec	Water Resistance	Fume Class*	Shelf Life
Emulex 510	1.15	16,300	Excellent	1	No change after 1 year
Emulex 520	1.16	15,200	"	1	"
Emulex 710	1.19	18,000	"	1	"
Emulex 730	1.21	17,000	"	1	"
Emulex 750	1.35	19,000	"	1	"

Table 2.6—Properties of watergels.

Product	Density g/cc	Velocity ft/sec	Water Resistance	Fume Class*	Shelf Life
Tovex 90	0.90	14.100	Good	1	1 year
Tovex 100	1.10	14,860	Excellent	1	"
Tovex 300	1.02	11,500	Good	A	"
Tovex 650	1.35	14,750	Excellent	1	"
Tovex 800	1.20	15,750	Excellent	1	"
Tovex T-1	0.25 lb/ft	22,000	Good	3	"

Table 2.7—Properties of two-component explosives.

Product	Density g/cc	Velocity ft/sec	Water Resistance	Fume Class*	Shelf Life
Thermex Y	1.22	20,000	Package only	1	1
Kinestick	1.1	18,000	Package only	1	1

2.2.1 Detonation Velocity

Detonation velocity (VOD) is an important property to consider when rating an explosive. It may be expressed as a confined or unconfined value and is normally given in feet per second (fps). The confined detonation velocity measures the speed at which the detonation wave travels through a column of explosive within a borehole or other confined space. The unconfined velocity indicates the speed of the detonation wave when the explosive is detonated in the open. Because explosives generally are used under some degree of confinement, the confined value is the more significant. Most manufacturers measure detonation velocity in an unconfined column of explosive 1¼ inches (3.18 cm) in diameter, although some measurements are made within the confinement of an iron pipe or using a different diameter of explosive. If confined velocities are not available, add 20 to 25 percent to the unconfined velocities to get an estimate of confined velocities.

The confined detonation velocity of commercial explosives varies from 5,000 to 25,000 fps (Tables 2.1 to 2.7). With cartridge explosives, the confined velocity is seldom attained because complete confinement is usually impossible. For blasting in hard rock, a high-velocity explosive (such as an emulsion) is preferred. In a softer or highly jointed rock, a low-velocity explosive (such as ANFO) with a heaving action may give satisfactory results at a lower cost.

Some explosives, particularly blasting agents such as ANFO, are more sensitive to diameter changes than others (Table 2.4). In charges with larger diameters, those 6 inches (15.2 cm) or more in diameter, the velocity may be medium to high. But as the diameter becomes smaller, the velocity is reduced until, at the blasting agent's critical diameter [about 2 inches (5 cm)], propagation is no longer assured and misfires are likely.

2.2.2 Density

The density of an explosive may be expressed in terms of specific gravity. Specific gravity is the ratio of the density of the explosive to the density of water under standard conditions. The density of commercial explosives ranges from 0.6 to 1.7 grams per cubic centimeter. For free-running explosives, the density is often specified as the pounds of explosive per foot of charge length in a given-size borehole. With few exceptions, denser explosives give higher detonation velocities and pressures.

Density is an important consideration when choosing an explosive. A dense explosive is needed for difficult blasting conditions or where fine fragmentation is desired. In easily fragmented rock or where fine fragmentation is not needed, a low-density explosive will often suffice. Low-density explosives are particularly useful when producing riprap or other coarse products.

The density of an explosive is also important when working in wet conditions. An explosive with a specific gravity of less than 1.0 will not sink in water.

2.2.3 Detonation and Borehole Pressure

Detonation pressure is a function of the detonation velocity and density of an explosive. A nomograph (Figure 2.2) can be used to approximate the detonation pressure of an explosive when the detonation velocity and specific gravity are known. Detonation pressure depends more on detonation velocity than specific gravity. A high detonation pressure is needed when blasting hard, dense rock. In softer rock, a lower pressure is sufficient. Detonation pressures of explosives range from 10 to more than 140 kilobars (1 kilobar = 14,504 pounds per square inch).

2.2.4 Water Resistance

An explosive's water resistance is a measure of its ability to withstand exposure to water without deteriorating or losing sensitivity. Sensitivity is the ease with which an explosive detonates. In dry work, water resistance is of no consequence. If water is standing in the borehole, and the time between loading and firing is fairly short, an explosive with a water-resistance rating of *good* is sufficient. If exposure to water is prolonged, or if water is percolating through the borehole, an explosive with *very good* to *excellent* water resistance is required.

In general, gelatins and emulsions offer the best water resistance. Higher-density explosives have fair to excellent water resistance, while low-density explosives and blasting agents have little or no water resistance. Brown nitrogen-oxide fumes after a blast often mean the explosive has deteriorated because of exposure to water.

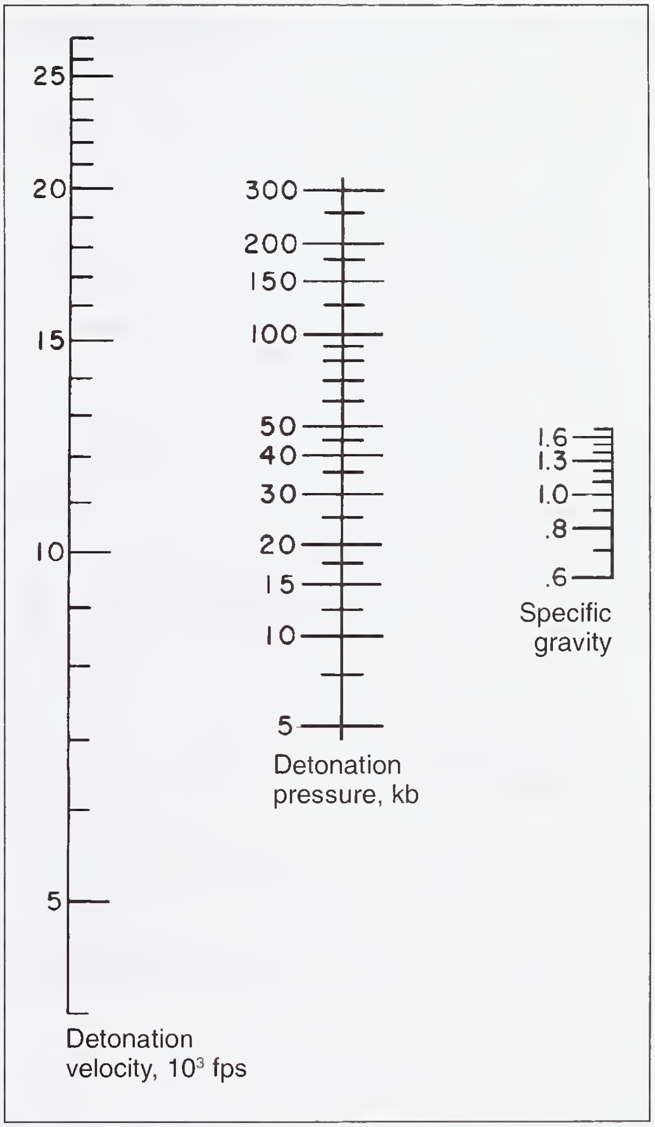


Figure 2.2—This nomograph can be used to determine detonation pressure.

2.2.5 Fume Class

Ideally, detonation of a commercial explosive produces water vapor, carbon dioxide, and nitrogen. In addition, undesirable poisonous gases, such as carbon monoxide and nitrogen oxides, are usually formed. These gases are known as fumes. The fume class of an explosive indicates the nature of the undesirable gases formed during detonation. Better

ratings are given to explosives producing smaller amounts of fumes. Fumes are not usually an important factor for open work. However, in confined spaces, the fume rating of an explosive is important. In any case, the Blaster should ensure that everyone stays away from fumes generated by a shot.

The Institute of Makers of Explosives has established a Fume Classification Standard based on the volume of poisonous gases emitted by a 1½- by 8-inch (3.81 x 20.32 cm) cartridge detonated under standardized conditions. High explosives may be classified as follows:

Class 1—Less than 0.16 cubic feet of toxic gas generated per 1¼ by 8 inches of cartridge (200 g of explosive).

Class 2—0.16 to 0.33 cubic feet of toxic gas generated per 1¼ by 8 inches of cartridge (200 g of explosive).

Class 3—0.33 to 0.67 cubic feet of toxic gas generated per 1¼ by 8 inches of cartridge (200 g of explosive).

2.2.6 Shelf Life

Shelf lives of various products are listed in Tables 2.1 to 2.7. For most explosives products a shelf life of 1 year is recommended, although satisfactory performance can be expected from some products after 2, 3, and even 4 years. Consult manufacturers and suppliers to determine shelf-life ratings longer than 1 year.

2.2.7 Permissibles or Permitted Explosives

A permissible explosive is one that has been approved by the U.S. Bureau of Mines or the British Ministry of Fuel and Power for use in gas- or dust-filled mines. When detonated or exploded, all explosives produce a flame that varies in volume, duration, and temperature. Black powder produces the longest lasting flame, while dynamites typically produce a shorter lasting, but more intense flame. Permissible explosives are designed to produce a flame of low volume, short duration, and low temperature. This is done by adding certain salts to the explosive formula to cool or quench the flame, preventing the ignition of gas or dust within the confined space of a mine.

Permissible explosives are generally modified types of gelatin or ammonia dynamites. They are similar in packaging and appearance to other dynamites.

2.3 Blasting Agents

A blasting agent is defined as any material or mixture consisting of a fuel and oxidizer used for blasting. Blasting agents consist primarily of inorganic nitrates and carbonaceous fuels (ammonium nitrate).

Blasting agents may be classified as dry blasting agents, watergels (slurries), or emulsions.

The addition of an explosive ingredient, such as TNT, changes the classification of the mixture from a blasting agent to an explosive. When unconfined, blasting agents cannot be detonated by means of a No. 8 test blasting cap (unless an explosive ingredient or sensitizer is added to the blasting agent). No. 8 test caps contain the equivalent of 2 grams of a mixture of 80-percent mercury fulminate and 20-percent potassium chlorate. The blasting agent *Nitro Carbo Nitrate* is a solid explosive made of ammonium nitrate, dinitro cotton, and other components. Nitro Carbo Nitrate is an official classification for interstate transportation.

2.3.1 Dry Blasting Agents

Dry blasting agents are basically a mixture of granular or prilled ammonium nitrate and a fuel such as fuel oil or other carbonaceous material.

The most commonly used dry blasting agent is a mixture of ammonium nitrate prills and fuel oil, commonly referred to as ANFO. Theoretically, the percentage of ingredients (by weight) in oxygen-balanced ANFO is 94.5 percent ammonium nitrate and 5.5 percent fuel oil. In actual practice the proportions are 94 percent and 6 percent. The extra fuel oil is added so that enough fuel oil is intimately combined with the ammonium nitrate to ensure an efficient chemical reaction.

Dry blasting agents (ANFO) are not cap-sensitive and must be initiated by a high-explosive primer or booster (Figure 2.3). To ensure efficient detonation of a blasting agent, a high-velocity primer or booster about the same diameter as the borehole must be used. Inadequate priming imparts a low initial-detonation velocity to a blasting agent. In extreme cases the reaction will die out, causing deflagration. When dry blasting agents are confined, they may attain detonation velocities between 12,000 and 18,000 fps. When the diameters are as small as 2 inches, velocity is reduced to about 6,000 fps, resulting in deflagration rather than detonation.

Figure 2.3—Booster with detonation cord.

The specific gravity of dry blasting agents varies from 0.5 to more than 1.0. The specific gravity of common ANFO varies from 0.80 to 0.85. Table 2.4 shows how the confined detonation velocity and the loading density of an ANFO mixture vary with borehole diameter. The range includes most common varieties of ANFO when poured into the borehole. Pneumatic loading results in higher detonation velocities and higher loading densities. The confined velocities also assume that a primer of sufficient size and velocity is used.

Advantages of dry blasting agents include safe transportation, storage, and handling, as well as ease of loading and relatively low price. In free-flowing form, the great advantage of dry blasting agents over cartridge explosives is that they completely fill the borehole. This ensures a more efficient use of explosive energy than can be obtained with cartridge explosives because the blasting agent is "directly coupled" to the rock being blasted.

ANFO's greatest disadvantage is that it is extremely hygroscopic (absorbs water easily). It should not be used under wet conditions because it may misfire. Some water-resistant ANFO products may be suitable in some wet conditions.

Cycling (the change in a material's crystal form with temperature) may occur with ANFO. The two temperatures at which cycling will occur under normal conditions are 0 °F and 90 °F. During the summer, cycling may occur daily in poorly ventilated powder magazines. When the temperature gets hotter than 90 °F and cools off, the prills break down into smaller crystals. This increases ANFO's density from 0.8 to 1.2 grams per cubic centimeter. Increased density increases the detonation velocity of the explosive. The total energy released by cycled ammonium nitrate can be 3.3 times greater than originally expected. As the cycling process continues, the entire mass will start to dissolve. After dissolving, it will start to recrystallize into large crystals. After cycling, ANFO may have very dense areas and areas of large crystals that are not as dense. The performance of the product may range from a more powerful explosive than originally predicted to one that will barely burn or will not detonate at all.

2.3.2 Watergels (Slurries)

Watergel explosives consist of oxidizing salts, fuels, and sensitizers dissolved or dispersed in a continuous liquid phase. The entire product is thickened and made water resistant by adding gels and cross-linking agents. The oxidizing salts are usually selected from ammonium nitrate or calcium nitrate. Aluminum, gilsonite, and oil are frequently used as fuels. Sensitization may be provided by chemical sensitizers, such as the nitrate salts of organic amines, nitrate esters of alcohols, perchlorate salts, or small particles of aluminum. Air bubbles may provide physical sensitization either alone or in combination with chemical sensitizers.

As early as the 1940's, DuPont began work on an ammonium-nitrate explosive consisting of ammonium nitrate, water/thickener, and a sensitizer. These early products were called watergels. The watergels were not commercialized in the 1940's due to the demand for small-diameter products. With the spread of large-diameter drilling equipment in the 1950's, the path was paved for commercial development. DuPont began manufacturing bagged watergels in 1958. At this

time a primer or booster was necessary for detonation. The early use of watergels was for large-diameter holes that were pumped from bulk trucks. Because watergels had such unique safety and performance features, DuPont began to develop a cap-sensitive product, *Tovex,* that was capable of propagating in a small-diameter borehole. With the development of Tovex in 1974, DuPont announced its intention to phase out of the dynamite business and convert its sales and manufacturing facilities to the new Tovex cartridge watergel explosives.

In the standard drop test, most dynamite detonates under an impact of a 4.4-pound weight dropped from a height of 15 inches. In the same type of test, Tovex was not initiated under the impact of an 11-pound weight at the maximum drop of 52 inches. In the bullet test, Tovex was placed against a metal plate and a 150-grain .30-'06 bullet was fired at a velocity of 2,625 fps from a range of 75 feet (22.86 m). The Tovex shattered, but did not detonate. A test conducted by the Canadian government enclosed 5 tons of Tovex in a truck and set it on fire. The Tovex burned, but did not detonate. Despite these impressive results, Tovex is an explosive and should be treated as such.

The densities of watergels range from about 0.80 to 1.60 g/cc, with most gels having a density between 1.0 and 1.35 g/cc. Velocities range from 11,000 to 22,000 fps. Watergels can be tamped more readily in small-diameter boreholes and can be loaded at a higher borehole density than most dense dynamites. For example, a 1¼-inch-diameter (3.18-cm) watergel at a 1.15 g/cc density will string load in a 1¾-inch (4.44-cm) borehole at about 0.60 lb/ft. It can easily be tamped to a borehole density of over 1 lb/ft.

One advantage of watergels is that they are significantly more resistant than dynamite to accidental initiation from abuse, impact, shock, or fire. The detonation velocity of most watergels increases with confinement making this product a good choice for small-diameter holes. Water resistance of watergels is generally excellent, but can be reduced if the product is not used properly. For best results, use as packaged or in accordance with manufacturer's recommendations.

The sensitivity of watergels to initiation is affected by temperature. In general, higher product temperatures increase sensitivity while lower product temperatures decrease it. Changing temperatures could require a change in primer size or detonation energy.

The product temperature should be measured if there is any question about priming requirements. The product temperature may change when the product is loaded into a borehole, but the product temperature will equalize in time to the borehole temperature. A cold product must be allowed to reach the minimum priming temperature before trying initiation without a booster.

Note: The minimum temperature that watergels will reliably detonate using a No. 8 blasting cap is about 30 °F (-1 °C). Use a booster on the cap when temperatures are below 30 °F.

2.3.3 Emulsions

Many explosives manufacturers began research and development on emulsions and slurries in the early 1960's. Emulsion explosives were first commercialized in the mid-1970's as blasting agents. These products used entrapped air, achieved by gassing. During 1980, the use of glass microballoons for sensitivity led to the commercialization of improved cap-sensitive emulsions. Further development has led to commercial permissible and seismic cap-sensitive emulsions as well as emulsion/ANFO blends. Emulsions are the first commercial explosives manufactured with all liquid oxidizers and liquid fuels. The liquid oxidizers are dispersed as microscopic droplets in the liquid fuel. The result is a very "intimate" mixture of these components, leading to an improved "intimate reaction" zone that produces a more complete and efficient explosive reaction.

In emulsions the traditional nitrate salts supply the oxidizers while the fuels continue to be mineral or organic carbon compounds. Manufactured emulsions are water-in-oil emulsions. The nitrate salt solution and water (oxidizer) are refined into a mixture of oils and waxes (fuels). After appropriate confinement, the minute oxidizer droplets are tightly oriented in the continuous phase of the fuels. The emulsifying agent in the fuel mixture stabilizes the emulsion, eliminating the ability of the oxidizer droplets to coalesce and separate from the fuel. Emulsions do not use explosive sensitizers. Emulsions do not become an explosive until microballoons, or air voids, have been added. For this reason, emulsions are perhaps the safest explosives (other than ANFO) for resistance to flame, impact, and friction. The viscosity of most emulsion formulations changes very little down to temperatures of 10 °F. They begin to get thinner when temp-eratures exceed 100 °F. Emulsions have a detonation velocity as high as 19,000 fps.

The oily surface of emulsions provides excellent water resistance. Emulsion explosives do not rely on packaging for any degree of water protection. The shelf life and stability of emulsion explosives are excellent with no change in their

explosive properties after 1 year. Studies show emulsions have a higher degree of resistance to detonation from standard impact and friction tests than either watergels (slurries), or dynamites. Emulsions are explosives and proper handling is required.

The type and quantity of air voids used to sensitize an emulsion dictate its sensitivity. The sensitivity of today's typical emulsions ranges from a high explosive sensitive to a No. 8 test cap at 10 °F to insensitive blasting agents that require a high-explosive booster for initiation.

Table 2.5 shows some properties of emulsion products.

Figure 2.4—Two-component explosives packaged in plastic tubes.

2.4 Nitroglycerin

Nitroglycerin-based products are being phased out. Safer products, such as watergels and emulsions, are taking their place.

2.5 Two-Component Explosives

Two-component cap-sensitive explosives consist of a liquid and a solid (powder). The powder is specially processed ammonium nitrate with no organic additives. It is supplied in a pouch or plastic tube (Figure 2.4). The liquid component is nitromethane, a nitroparaffin that has a flammability like gasoline but with a higher flash point. The liquid component is usually supplied in a plastic tube. The components are not considered an explosive until they are mixed (Figure 2.5).

Figure 2.5—Adding liquid sensitizer to ammonium nitrate pouch.

Two-component explosives range from a density of 1.2 to 1.3 g/cc. Detonation velocity ranges from 18,000 fps to 20,000+ fps. After two-component explosives are properly mixed, they become Class A (1.1D) explosives, are cap-sensitive, and may be initiated with an electric blasting cap or detonating (det) cord. Mixing may take anywhere from 10 minutes to 2 hours, depending on the size of the charge and the compaction of the solid component. The charges can be loaded into the holes during this time. Allow adequate time for the liquid to penetrate into the solid powder.

The plastic tubes are constructed with a built-in cap well. If det cord is used, there must be intimate contact with the plastic tube. It is recommended that 50-grain det cord be used with the plastic tubes. If the detonating cord is inserted into the pouch, 25-grain cord may be used if a knot is tied on the end to act as a minibooster.

Two-component explosives offer an advantage in storage and transportation because they are not classified as an explosive until they are mixed. Both components should be stored separately. Liquid nitromethane is considered flammable and should be treated as such. Store nitromethane as packaged in a locked building or cabinet labeled *Flammable Liquid*. Nitromethane has a freezing point of 19 °F (-7 °C) and a boiling point of 215 °F (101 °C). Solid-powder ammonium nitrate is considered an oxidizer with a boiling point of 410 °F (210 °C). Store ammonium nitrate as packaged in a dry locked building or cabinet labeled *Oxidizer*. When the two components are mixed, they become a Class A (1.1D) explosive and must be stored in an approved magazine.

The shelf life of unmixed two-component explosives should exceed the shelf lives of dynamite, emulsions, and watergels. Over time nitromethane will evaporate through the plastic tube. Two tubes of liquid may be needed for each tube or pouch of powder. For this reason, nitromethane's recommended shelf life is 1 year (Table 2.7).

To disarm or render the mixed product useless, pour the armed product onto the ground. Pour water over it or spread it around with a stick. The liquid nitromethane will evaporate, leaving ammonium nitrate (fertilizer) on the ground.

2.6 Military Explosives

Several compounds and mixtures originally developed for military purposes have commercial applications. Only those with significant industrial applications are discussed.

2.6.1 Trinitrotoluene (TNT)

TNT was used commercially as early as 1891. It is a stable, cap-sensitive compound, with good water resistance. Cast TNT has a density of 1.56 g/cc and a confined detonation velocity of about 22,000 fps. It is used as a primer and booster for blasting agents.

TNT may be used as a sensitizer for slurries. It is an ingredient of several explosive mixtures, such as pentolite and Composition B.

2.6.2 Pentaerythritoltetranitrate (PETN)

PETN has a crystal density of 1.76 g/cc and a confined detonation velocity of over 25,000 fps.

In various degrees of granulation, PETN is used as a priming composition in detonators, a base charge in blasting caps, a core load for det cord, and in the manufacture of pentolite. The use of PETN in detonation cord is discussed in Chapter 3.4. PETN is a secondary explosive. It is not as sensitive as primary explosives, such as lead azide or nitroglycerin. Cast primers of PETN are supplied as shape charges.

2.6.3 Cyclotrimethylenetrinitramine (RDX)

RDX is second in strength to nitroglycerin among common explosive substances. When compressed to a density of 1.70 g/cc, it has a confined detonation velocity of 27,000 fps.

RDX is the primary ingredient in Composition B. The high detonation velocity and plasticity of RDX make it ideal for a shaped charge for oil-well perforators (jet perforators) and furnace tappers (jet tappers). RDX is often used as the base charge for detonators.

2.6.4 Composition B

Composition B is a mixture of RDX, TNT, and 1 to 4 percent of wax. When cast, it has a density of 1.65 g/cc and a detonation velocity of about 25,000 fps. Composition B (like pentolite) is used in the cast form as a primer and booster for blasting agents.

2.6.5 Pentolite

Pentolite is a mixture of PETN and TNT. Pentolite contains about 20- to 50-percent PETN, and the rest of the mixture is TNT. PETN was originally used for burster charges in military explosive devices and is now used for commercial boosters.

Chapter 3—Detonators and Initiation Systems

3.1 General

Detonators of various types are used to initiate explosives. Because detonators are made to explode, they must be treated with extreme caution. They must not be physically abused, altered in any manner, or exposed to sources of extraneous electricity. Detonators are supplied with brightly colored wires, tubes, and plastic connectors that are particularly attractive to children. They must be closely inventoried and secured when not in use.

Detonators fall into two distinct categories depending on their prime source of energy to initiate: nonelectric and electric.

It may deflagrate, but it will not detonate. Most sources of extraneous electricity that could detonate a standard EBC are not a hazard when using an EBW (Table 3.1). It is not necessary to check circuits for extraneous electricity when using EBW's.

Table 3.1—Comparison of electric EBC to EBW detonators.

	EBC	EBW
Current ______ Threshold	1.0 amp	200 amp
Current ______ Operating	5.0 amp	>450 amps
Voltage ______ Threshold	<20 volt	500 volt
Voltage ______ Operating	20 volt	3000 volt
Energy ______ Threshold	0.2 joule	0.2 joule
Power ______ Threshold	1 watt	100,000 watt
Function time __ Typical	1 millisec	1 microsec

3.2 Electric Detonators

3.2.1 Exploding Bridgewire (EBW) Detonators

The inert components (shell and wires) of an EBW are similar to standard electric blasting caps (EBC's). The components consist of two insulated leg wires connected by a thin-filament bridgewire (Figure 3.1) in an insulated metal capsule. The major difference is that EBW's contain no primary explosives. Therefore, they are not susceptible to premature detonation due to shock and heat. The fine gold bridgewire is in contact with PETN, a secondary explosive. For EBW's to function properly, a powerful electric current must be delivered to the bridgewire in a very short period of time. This rapidly heats the wire to the vaporization phase. The wire explodes with enough force to detonate the secondary explosive. If either the amount of current or the rate of application is incorrect, the EBW will not function properly.

Neither static electricity, radio transmissions, automotive batteries nor ignition systems, chain saw magnetos, or most generator-type blasting machines will detonate an EBW. A special field-firing set, Model FS-9, capable of generating a timed 3,000-volt pulse, is required to detonate EBW's (Figure 3.2). A special model of the field-firing set, the FS-10, is designed for seismic work.

The three types of EBW detonators typically used in blasting operations are the RP-80, RP-83, and RP-501 (Figure 3.3). EBW detonators may be used with detonating cord, bulk explosives, or cartridges of cap-sensitive explosives. RP-80 detonators with cord adapters are used only with det cord. RP-80's are directional, while the RP-83 and RP-501 are not. The RP-501 is a lower cost version of the RP-80 and is the most widely used of the three EBW's because of its cost. It is not waterproof.

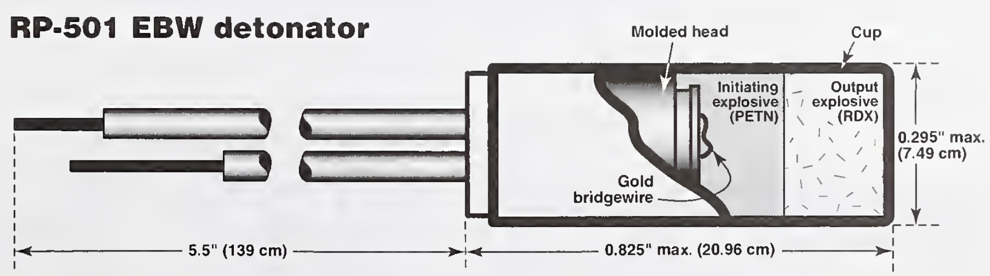


Figure 3.1—Exploding bridgewire (EBW) detonator model RP-501.

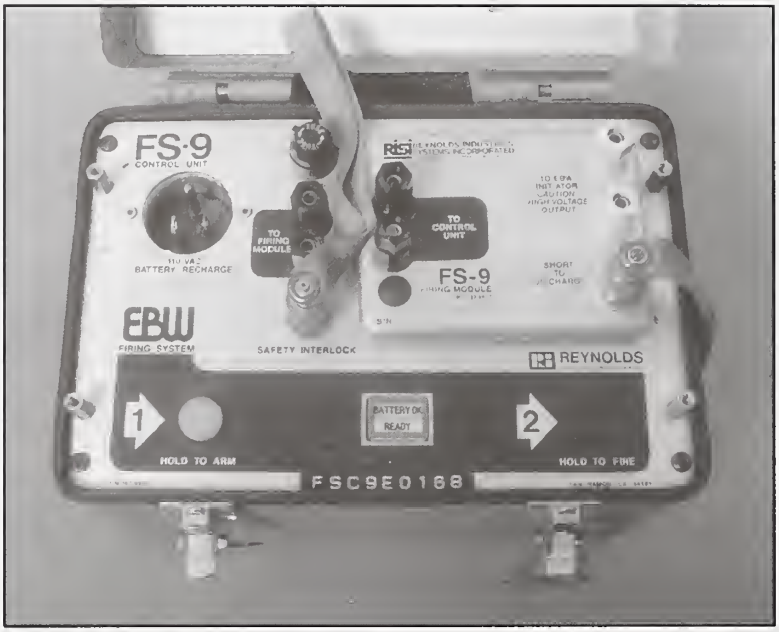


Figure 3.2—The FS-9 EBW firing set.

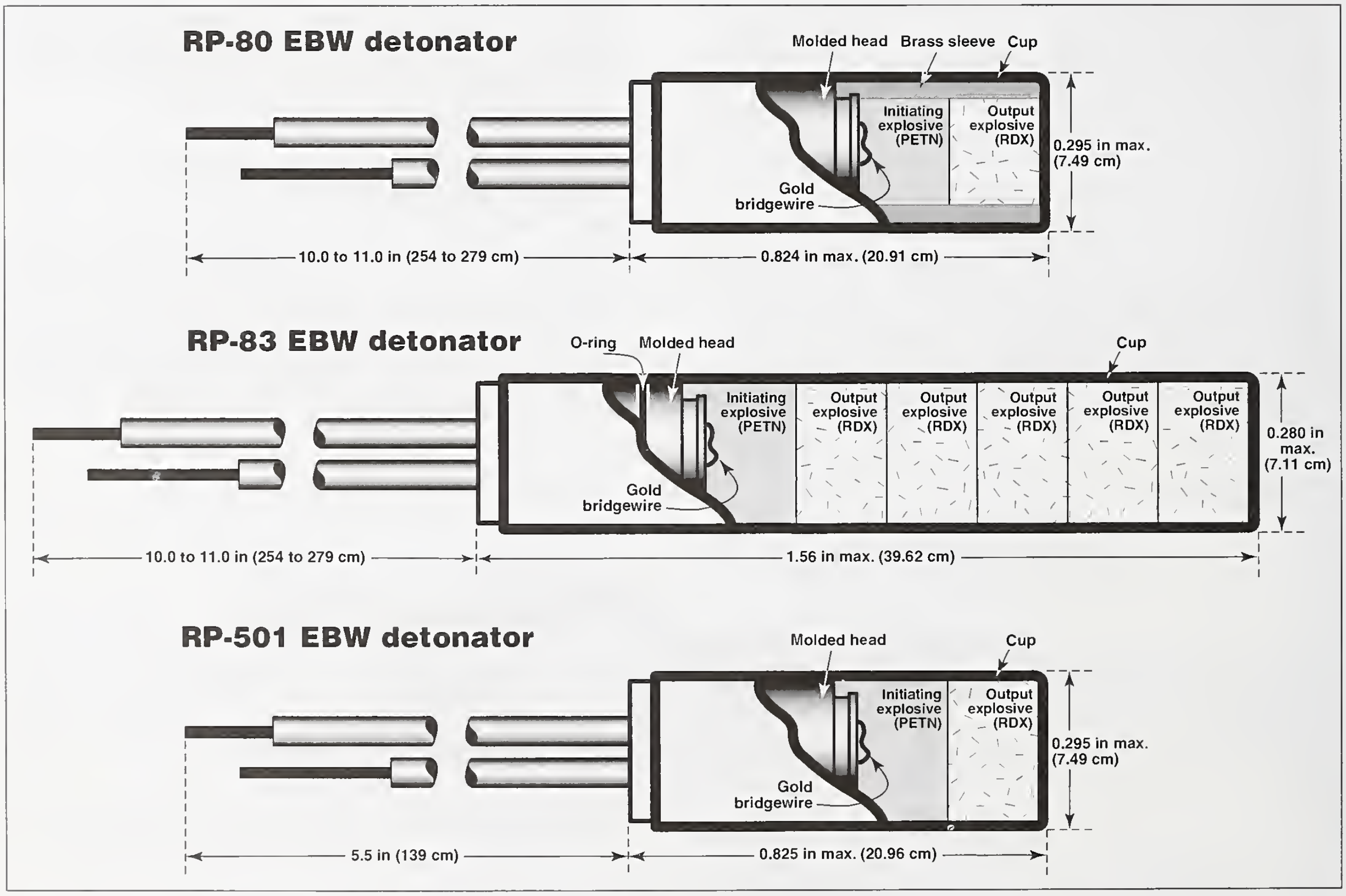


Figure 3.3—Exploding bridgewire detonator models RP-80, RP-83, and RP-501.

An EBW can be inserted directly into explosives or it can be used to initiate detonating cord, similar to the way EBC's are used. A maximum of six EBW detonators can be fired simultaneously in series. Because problems in circuit design can cause misfires, consult the manufacturer before firing more than two EBW's in series.

Since an EBW contains only secondary explosives (PETN), delay detonators are not available. EBW's are recommended for situations where static or other extraneous electricity is a problem, where fire or impact are factors to be considered, and where unit cost is not extremely important.

When using EBW's, provide enough lead wire to permit the Blaster and crew to be at least 500 airline feet from the nearest explosive. Use 20-gauge or larger insulated copper wire. Ensure that the wire from the module to the detonator is in good condition and the insulation is intact. A small spot where insulation has been scraped off will cause a misfire.

3.2.2 Electric Blasting Caps (EBC's)

Until recently, the EBC was the most common detonator for initiating high explosives. The cap may be inserted directly into the explosive cartridge or used in conjunction with det cord. An electric blasting cap consists of two insulated leg wires connected by a thin-filament bridgewire (Figure 3.4) in an insulated metal capsule. When enough current is applied to the leg wires (typically 0.25 amps) the bridgewire gives off heat energy and ignites a flash charge of a heat-sensitive explosive, usually lead azide. The explosion of the flash charge detonates a primary charge, which in turn detonates a base charge of powerful explosive, such as RDX or PETN. In some cases, the flash and primary charges are combined. The base charge of the cap detonates with sufficient force to initiate a cap-sensitive explosive or detonating cord.

Electric blasting caps have a resistance of about 2 ohms. In a series circuit where the resistance of the wire and the number of caps are known, it is easy for a Blaster to use a galvanometer (Figure 3.5) to ensure that all the caps are wired into the circuit properly. The total resistance of the circuit should equal the resistance of the wire plus the number of caps times 2 ohms (Figure 3.6a). If the resistance is too high, a bad connection may cause a misfire. If the resistance is too low, a cap did not get wired into the circuit. Some typical circuits are shown in Figure 3.6b.

Figure 3.5—Use a Blaster's galvanometer to check for continuity and open circuits.

An advantage of electric blasting caps over other systems is the variety of delay periods available and the ability of the Blaster to choose the exact time of detonation for each cap.

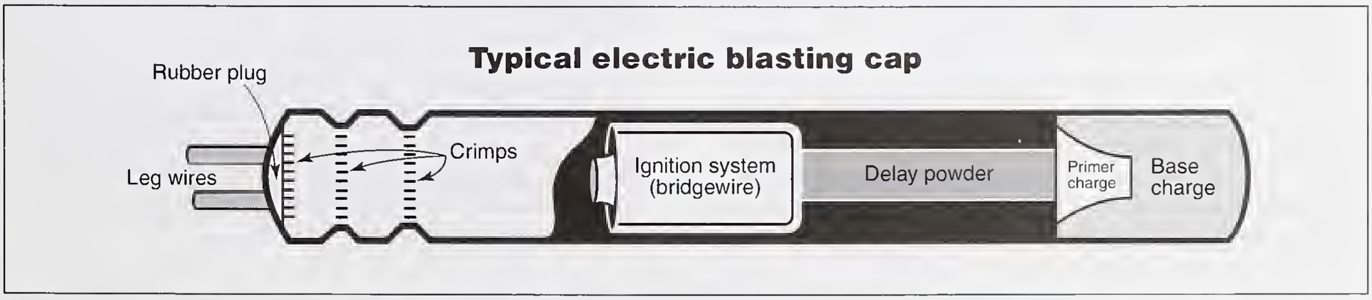


Figure 3.4—Typical electric blasting cap (EBC).

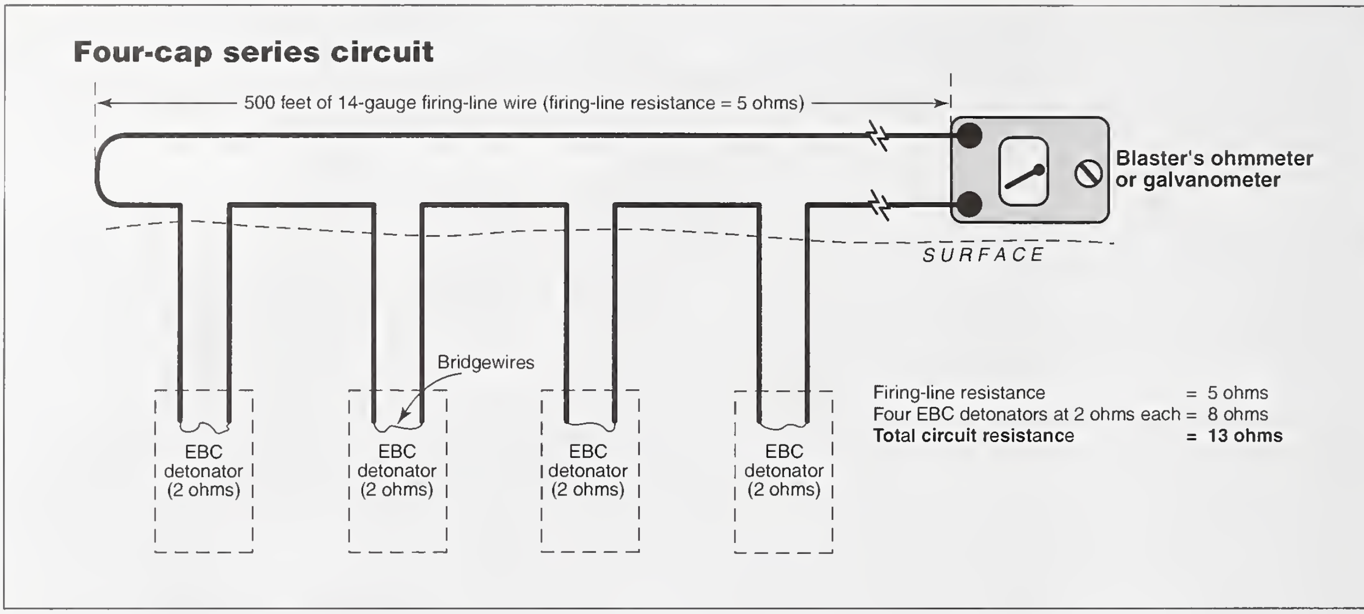


Figure 3.6a—Typical four-cap series circuit.

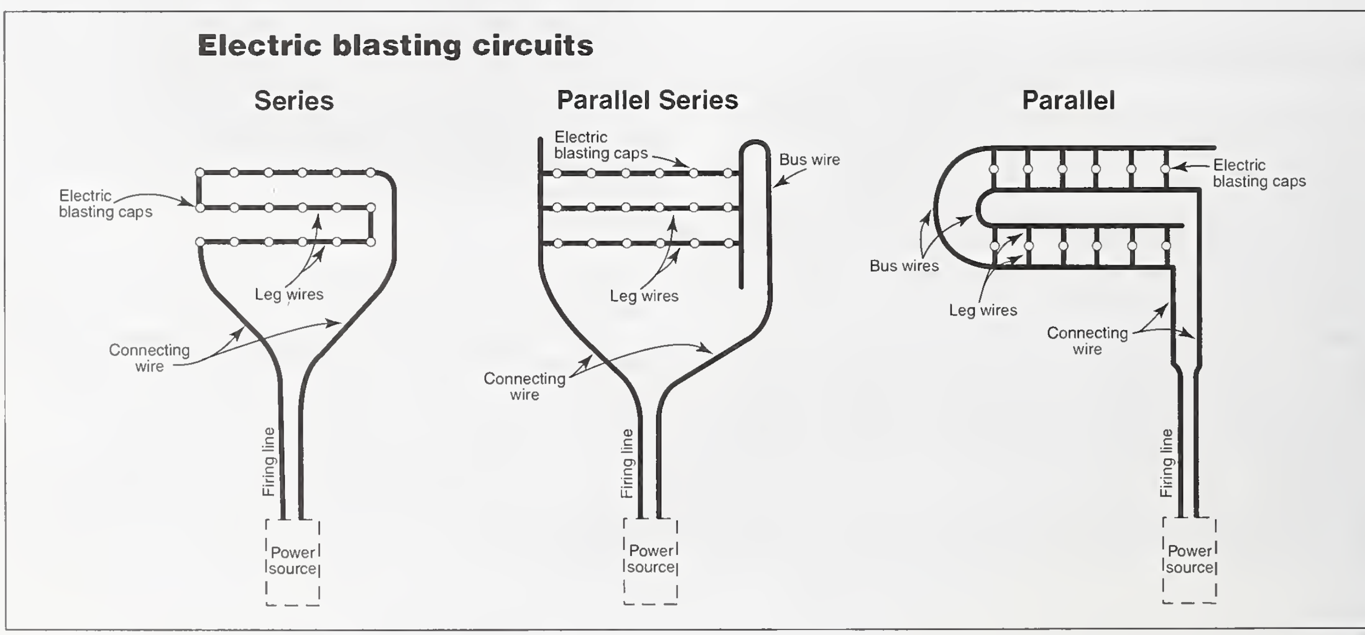


Figure 3.6b—Types of electric blasting circuits.

When working in populated areas, vibration, noise, and resulting public-relations problems are reduced by using delay blasting caps instead of having all caps detonate simultaneously or having to use trunklines and downlines of detonation cord. In a delay electric blasting cap, a delay element containing specially blended powders is interposed between the bridgewire and the primer charge. The delay element is accurately calibrated to give a specified time lapse between the application of electric current and the detonation of the base charge.

Two basic series of delays are available: short (millisecond delays) and long (slow delays).

The millisecond delays have delay increments ranging from 25 to 50 milliseconds; the long delays have delay increments ranging from 0.5 to 1 second. In normal blasting, where maximum fragmentation is desired, millisecond delays produce good breakage and reduce airblast and ground vibrations. Slow delays are primarily for underground or tunnel work, where they provide enough time for rock movement between delay periods. Long delays are likely to result in coarser fragmentation than millisecond delays.

EBC Handling Precautions—When using EBC's, avoid stray electric currents, such as those caused by power cables lying on the ground, particularly when the ground is wet. A Blaster's multimeter (Figure 3.7) must be used continuously to monitor stray current in electric circuits. If the stray current is above 0.05 amps, standard electric blasting caps cannot be used. Extraneous electricity can be measured using either digital or analog Blaster's multimeters. The meter must be capable of reading currents less than 0.05 amperes.

Figure 3.7—A Blaster's multimeter can be used to check for stray current and resistance.

* Do not throw electric blasting-cap leg wires through the air. Unfold or unroll wires near the ground.

* Do not load boreholes when an electrical storm is in progress or approaching.

  –If holes are loaded and a storm occurs, keep the danger area clear and post flaggers in the same manner as when shots are fired.

  –If holes are loaded, but not connected to the lead wire, do not shunt the series; leave it open.

* Use EBW's, detonating cord, or other nonelectric systems in place of electric blasting caps in areas near powerlines. If the power cannot be interrupted, use EBW's or nonelectric detonators on work within 300 feet (91 m) of the powerline. EBW's and nonelectric detonators must also be used within the minimum distance from a permanent radio or television transmitting station (Tables 3.2 through 3.6).

* Although clothing is not a major cause of accidental detonation, it can generate enough static electricity to detonate electric blasting caps. The most hazardous condition occurs when wearing clothing of different fabrics, particularly wool with dacron or nylon on a dry, cold day. Take these precautions:

  –Wear cotton or wool. Avoid wearing synthetics such as dacron or nylon, particularly with wool garments.

  –Do not remove your coat or sweater while working with electric detonators.

  –Discharge static electricity by grounding your body for at least 10 seconds.

  –When hazardous amounts of static electricity exist (greater than 0.05 amps), use EBW's or nonelectric initiation systems.

Consult manufacturer's data for electric current requirements. Requirements vary from brand to brand. Mixing brands in a circuit is not recommended because mixing can cause a misfire. Use appropriate initiating devices that will initiate the number of detonators used in the circuit. A typical small-capacitor discharge initiator is shown in Figure 3.8. Do not use batteries to initiate electric detonators.

Table 3.2—Recommended distances for commercial AM broadcast transmitters 0.535 to 1.605 MHz.

Transmitter power [1] (watts)	Minimum distance (feet)
Up to 4,000	750
5,000	850
10,000	1,200
25,000	2,000
50,000[2]	2,800
100,000	3,900
500,000	8,800

1—Power delivered to antenna.
2—50,000 watts is the present maximum power of U.S. broadcast transmitters in this frequency range.

Table 3.3—Recommended distances for transmitters up to 30 MHz (excluding AM broadcast) calculated for a specific loop-pickup configuration[1].

Transmitter power [2] (watts)	Minimum distance (feet)
100	750
500	1,700
1,000	2,400
5,000	5,500
50,000	17,000
500,000[3]	55,000

1—This table should be applied to International Broadcast Transmitters in the 10- to 25-MHz range.
2—Power delivered to antenna.
3—Present maximum for International Broadcast.

Table 3.5—Recommended distances for VHF TV and FM broadcasting transmitters.

Effective radiated power (watts)	Minimum distance (feet)	
	Channels 2 to 6 and FM	Channels 7 to 13
Up to 1,000	1,000	750
10,000	1,800	1,300
100,000[1]	3,200	2,300
316,000[2]	4,300	3,000
1,000,000	5,800	4,000
10,000,000	10,200	7,400

1—Present maximum power channels 2 to 6 and FM 100,000 watts.
2—Present maximum power channels 7 to 13–316,000 watts.

Table 3.6—Recommended distances from UHF TV transmitters.

Effective radiated power (watts)	Minimum distance (feet)
Up to 10,000	600
1,000,000	2,000
5,000,000[1]	3,000
100,000,000	6,000

1—Present maximum power channels 14 to 83—5,000,000 watts (from the Institute of Makers of Explosives, Publication 20, *Safety Guide for the Prevention of Radio Frequency Radiation Hazards in the Use of Electric Blasting Caps,* March 1971).

Table 3.4—Recommended minimum distance (feet) of mobile transmitters including amateur and Citizens' Band.

Transmitter[1] power (watts)	MF 1.6 to 3.4 MHz industrial	HF 28 to 29.7 MHz amateur	35 to 36 MHz public use 42 to 44 MHz public use 50 to 54 MHz amateur	144 to 148 MHz amateur 150.8 to 161.6 MHz public use	UHF 450 to 470 MHz public use
10	40	100	40	15	10
50	90	220	90	35	20
100	125	310	130	50	30
180[2]	–	–	–	65	40
250	200	490	205	75	45
500[3]	–	–	290	–	–
600[4]	300	760	315	115	70
1,000[5]	400	980	410	150	90
10,000[6]	1,250	–	1,300	–	–
Citizens' Band (Walkie-Talkie): 5 watts, minimum distance 5 feet, 26.96 to 27.23 MHz.					

1—Power delivered to antenna.
2—Maximum power for two-way mobile units in VHF (150.8- to 161.6-MHz range) and for two-way mobile and fixed-station units in UHF (450- to 460-MHz range).
3—Maximum power for major VHF two-way mobile and fixed station units in 35- to 44-MHz range.
4—Maximum power for two-way fixed station units in VHF (150.8- to 161.6-MHz range).
5—Maximum power for amateur radio mobile units.
6—Maximum power for some base stations in 42- to 44-MHz band and 1.6- to 1.8-MHz band.

Figure 3.8—Capacitor discharge initiator for electric blasting caps.

3.3 Nonelectric Detonators

3.3.1 Nonel, Primadet, and Shock Star

Nonel, Primadet, and Shock Star are now the most widely used nonelectric detonators in construction and mining operations. A nonelectric detonator consists of a 0.12-inch-diameter plastic tube with a thin reactive coating on the inside surface (Figure 3.9). When activated with a spark initiator, EBW, EBC, or detonating cord, the tube transmits a low-energy signal by a shock wave similar to that caused by a dust explosion. The signal will propagate around sharp bends and through kinks. Because such a small amount of reactive material is used, the reaction will not initiate explosives. The tube remains intact after transmitting the shock wave. Noise levels are very low.

Nonelectric systems are not initiated by stray currents outside of the tube, fire, most light impacts, shock, or friction hazards that are encountered in normal blasting work during construction and mining operations. Shock initiators using shotgun shell primers are used to initiate nonelectric shock tube (Figure 3.10). The unprotected detonator end of a nonelectric system is susceptible to initiation by shock or heat. Handle nonelectric detonators with the same care as electric blasting caps.

Nonelectric detonators are available in several factory-assembled lengths with nonelectric delay detonators crimped on one end that will detonate cap-sensitive cartridge explosives. Various delay periods can be assembled depending on vibration control and fragmentation size requirements. Consult the manufacturer's literature for methods of connecting surface hole-for-hole and row-for-row delays (Figure 3.11).

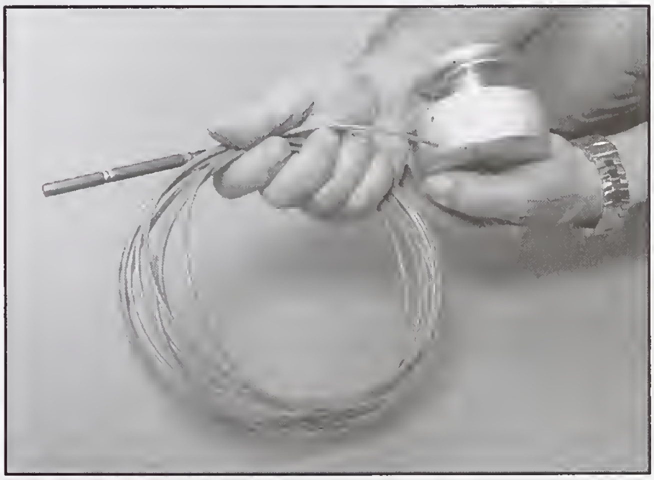


Figure 3.10—Nonelectric shot-shell-primer initiator.

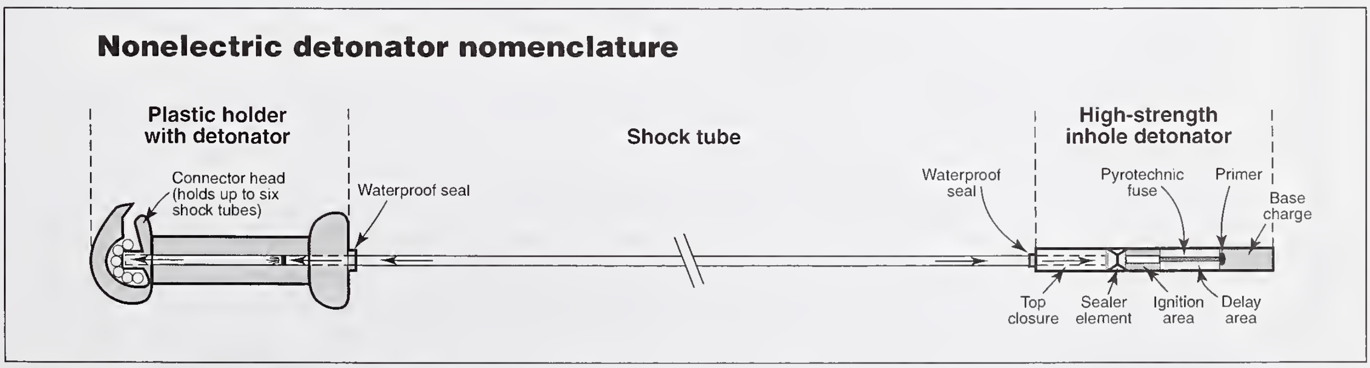


Figure 3.9—Nonelectric detonator nomenclature.

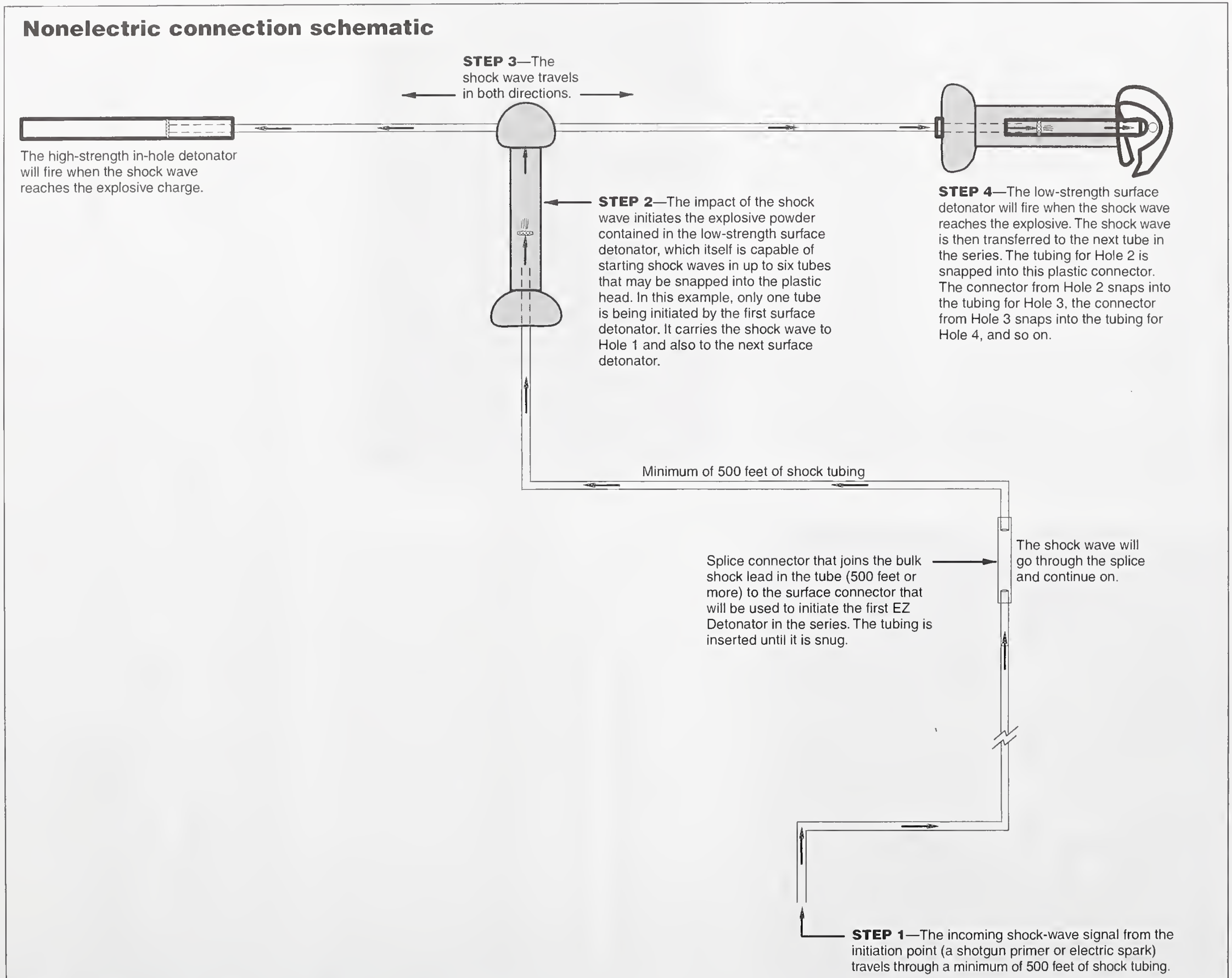


Figure 3.11—Nonelectric connection schematic.

3.3.2 Cap-and-Fuse Assemblies

Cap-and-fuse assemblies have not been used on Forest Service projects since 1996. The assemblies are included in this guide because Forest Service Blasters might encounter such devices during routine inspections or when explosives and detonators have been abandoned.

Cap-and-fuse assemblies consist of a blasting cap and a fuse that is crimped in place (Figure 3.12). Sometimes the caps may be found in boxes separate from rolls of fuse. The blasting caps are susceptible to accidental initiation from excess heat, friction, impact, or static electricity. They must be handled with great care. The fuse is typically white or orange, but other colors may be found including green fuse (military) or red fuse (foreign countries). High-quality fuse has a consistent burning rate of 40 seconds per foot at sea level. Other brands from foreign countries may vary from this standard considerably and may burn hot enough to ignite cast boosters.

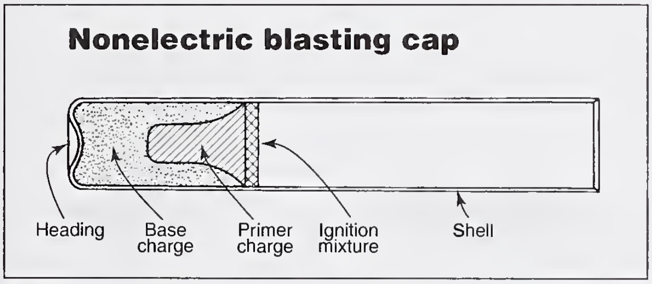


Figure 3.12—Blasting cap used in cap-and-fuse assemblies.

The fuse end of the assembly is generally lit with a pull-wire igniter. Once the fuse is lit, all control of the shot is lost. In case of a misfire, the Blaster must wait at least 1 hour before returning to the site!

3.4 Detonating Cord

Detonating cord consists of a core of high explosive, usually PETN, in a waterproof plastic sheath with a reinforcing cover of textile, plastic, and waterproofing materials (Figure 3.13). Different reinforcing covers have different degrees of tensile strength, abrasion resistance, and flexibility. Detonating cord has core loads ranging from 1 grain/ft to 400 grains/ft of PETN. All grades can be detonated with a blasting cap and have a detonation velocity of 22,000 fps or more. Care

Figure 3.13—Types of detonating cord.

must be exercised when using detonation cord around dry brush because it produces a flash that can start fires.

A PETN core load of 50 grains/ft is used for most applications.

Detonating cord's insensitivity to external shock and friction makes it ideal for use as both a downline and trunkline for primary blasting (Figure 3.14). The blasting cap need not be connected into the circuit until just before firing, eliminating most of the hazards of premature detonation.

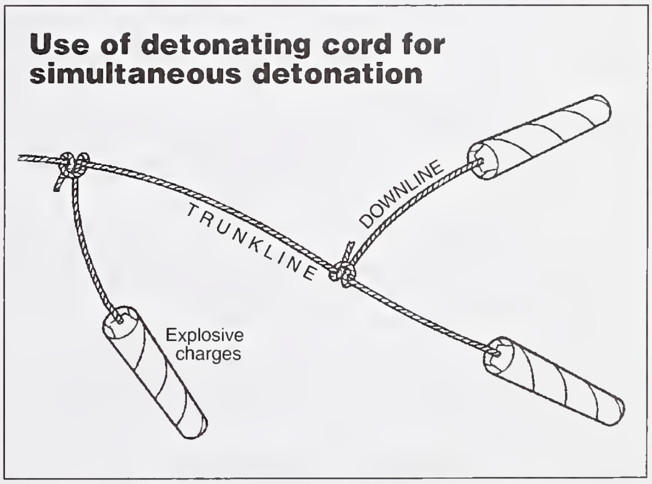


Figure 3.14—Detonation cord can be used to simultaneously detonate explosives.

A 25- or 50-gr/ft detonating cord will detonate most cap-sensitive explosives it contacts. However, simply lacing detonating cord through watergels and emulsions will not guarantee detonation. Often the explosive simply deflagrates because the detonating cord does not transmit as much energy laterally as it does longitudinally. The 50-gr/ft det cord is recommended for most uses. However, even 50-gr/ft detonating cord will not reliably detonate a blasting agent. A knot should be tied in the end of the detonating cord to act as a minibooster to ensure detonation of watergels and emulsions.

Detonating cord has wide application in underwater work. In a wet environment, the ends of the detonating cord should be protected from water. PETN will slowly absorb water and become insensitive to initiation. Even when detonating cord is damp, it detonates if it is initiated on a dry end.

Millisecond-delay connectors are available for multiple downhole delay shots. Connectors are tied between two ends of detonating cord in the trunkline, allowing the use of an unlimited number of delay periods. Delay connectors are commonly available in periods of 5, 9, 17, 25, 35, and 45 milliseconds.

Select a det cord consistent with the size and physical condition of the borehole, stemming, and the type of explosive. Using detonating cord for priming in small-diameter boreholes often results in the stemming being blown out of the borehole, resulting in increased flyrock. If ANFO or emulsion is used for stemming, the cord can burn (deflagrate) up to one-third of the ANFO or emulsion, making the shot much less effective. Top priming is recommended when using det cord downlines.

Trunkline cord should be 25 gr/ft or larger. Smaller cord will often work for downlines. However, many explosives, including some cast primers, are not reliably initiated by 25-gr/ft cord.

Handling Precautions—Handle and use detonating cord with the same respect and care given other explosives.

Always cut detonating cord with a sharp knife. Never cut det cord with devices that produce metal-to-metal contact, such as scissors, wire cutters, crimpers, or similar instruments. Never strike det cord with a blunt object.

Detonating cord less than 18 gr/ft will not reliably initiate larger cord.

Cut the line of detonating cord extending from a borehole or from a charge from the supply spool before loading the remainder of the borehole or placing additional charges.

Handle and use detonating cord with care to avoid damaging or severing the cord while loading and hooking up.

Make sure det cord connections are complete and positive in accordance with manufacturer's recommendations (Figure 3.15). All connections should be at right angles because sharp angles can cause cutoff. Trim excess cord after tying into the trunkline to prevent cutoff.

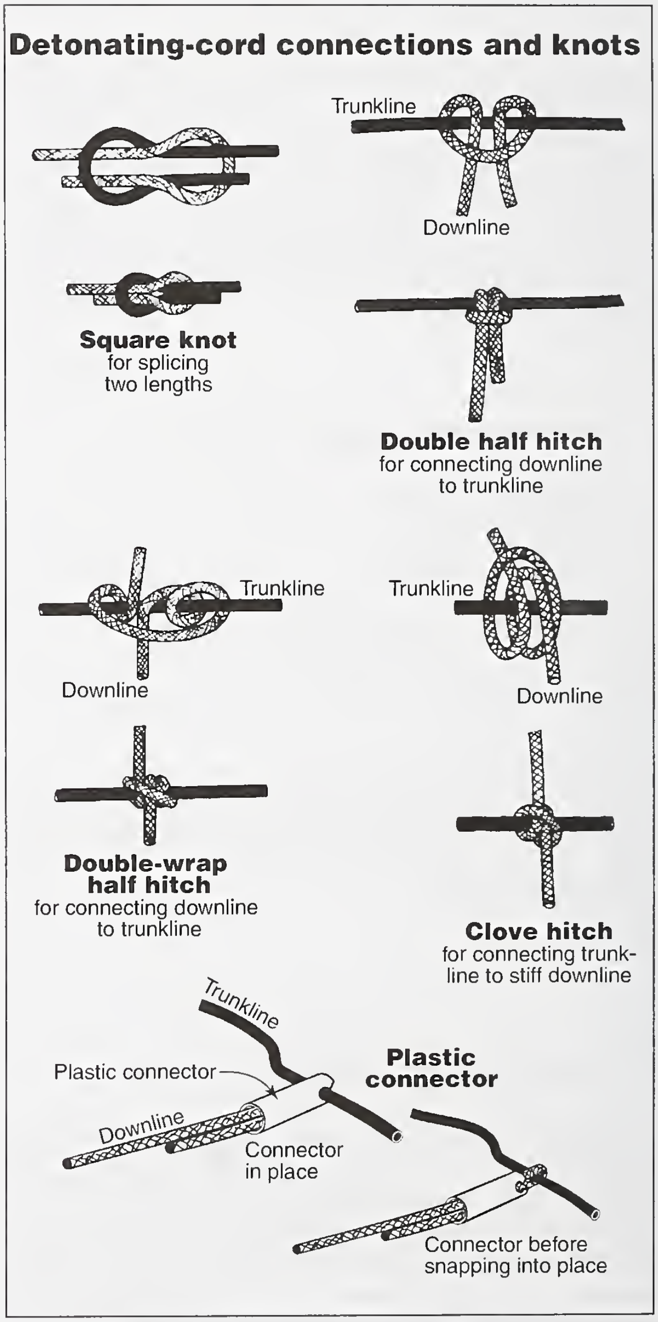


Figure 3.15—Detonating-cord connections and knots *(continued on next page).*

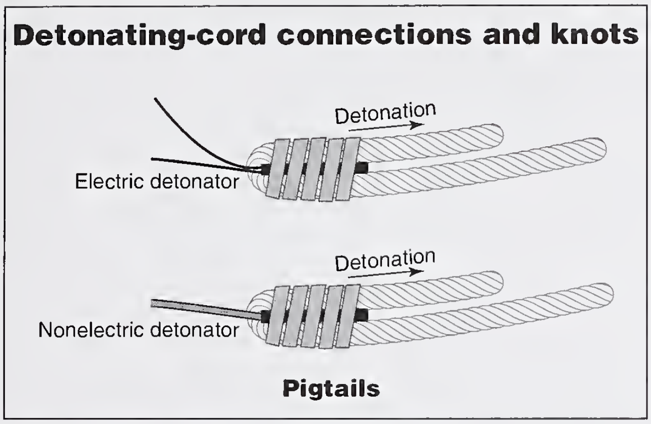


Figure 3.15—*Continued*.

Do not kink, bend, scrape, or leave slack in the trunkline cords or borehole downlines. Make sure all cut ends are free of water, oil, or other contaminants. Although det cord is water resistant, water penetrating through exposed cord ends or cracks in the covering can result in a cutoff or a misfire.

For multiple-hole shots, provide at least two paths of detonation to each borehole (Figures 3.16a and 3.16b) by using crossties between trunklines at regular intervals. Visually inspect the entire cord layout to ensure all connections are correct, and that no cord crosses over another cord.

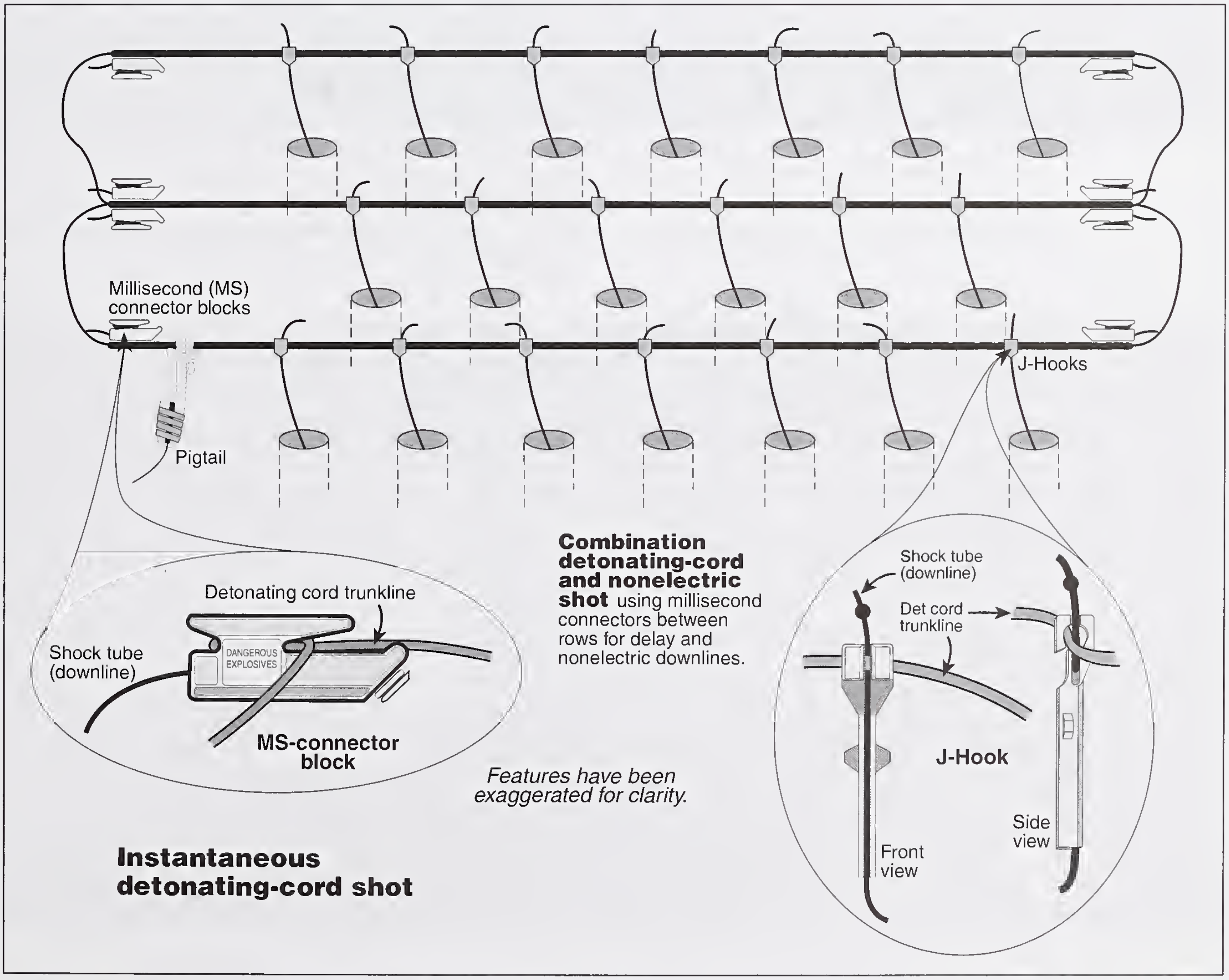


Figure 3.16a—One of two types of instantaneous det-cord shots.

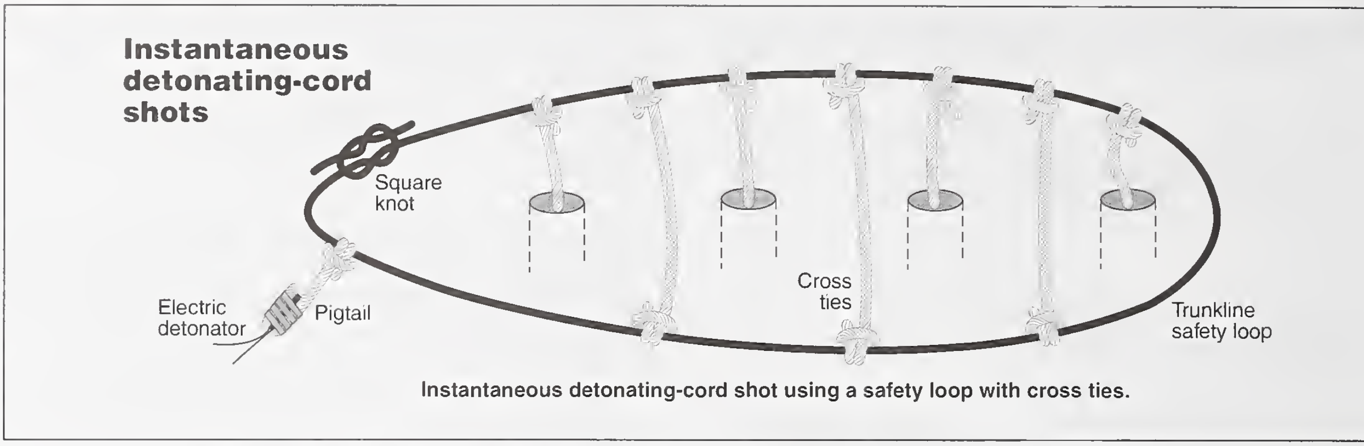


Figure 3.16b—An instantaneous detonating-cord shot using a safety loop with crossties.

Millisecond (MS) connectors and delays may be used between trunklines or boreholes to establish the sequence of the blast. These connectors are blasting caps and need to be protected from heat, impact, and friction. Follow all of the manufacturer's recommendations.

3.5 Primers and Boosters

Blasting agents are not typically cap sensitive. The initiation sensitivity is so low that a primer (cap and booster) is required for adequate initiation. Boosters are supplied in a variety of sizes (Figures 3.17a and 3.17b). Generally boosters are a cast PETN product. A hole in each cast booster accepts det cord (usually 25 or 50 gr/ft), a No. 6 or 8 blasting cap (EBW or EBC), or both. ***Never*** attempt to enlarge a hole that will not accept det cord or a detonator.

Figure 3.17a—Boosters are used to initiate noncapsensitive products like ANFO.

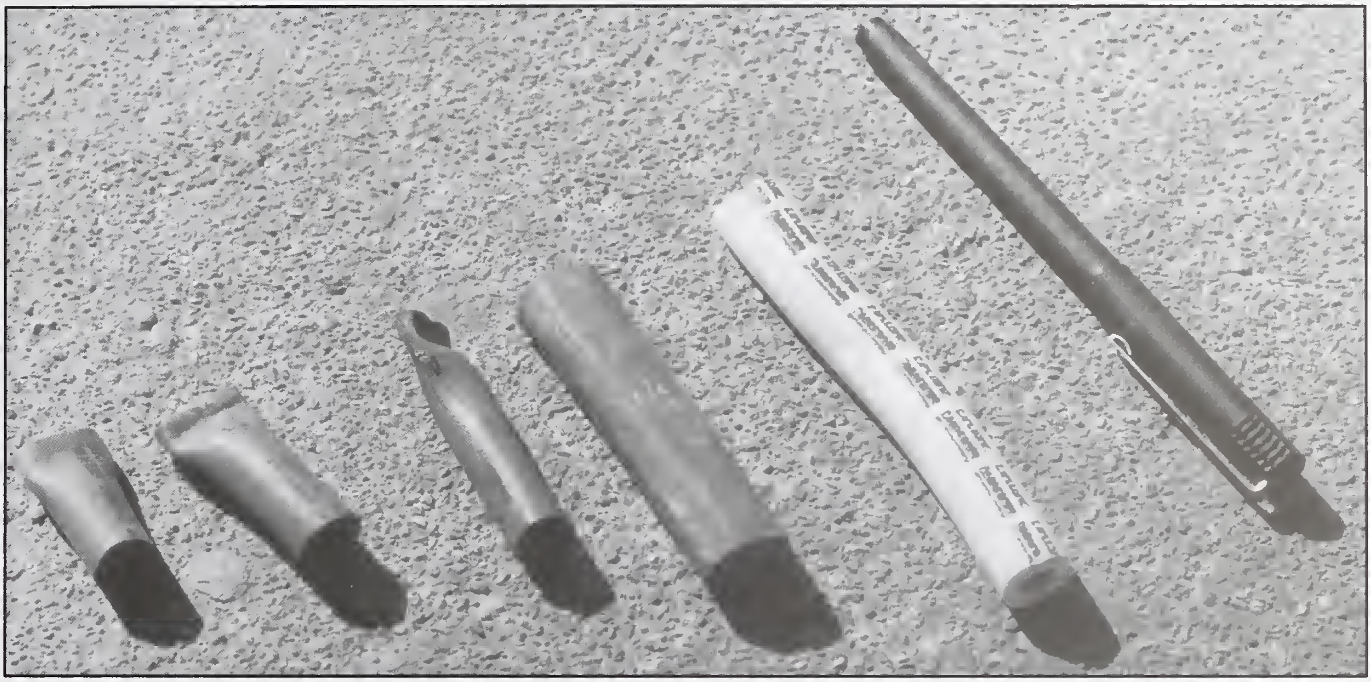


Figure 3.17b—Small boosters are also used to initiate noncapsensitive products like ANFO.

Make up primers using boosters in accordance with methods outlined in the Institute of Makers of Explosives Publication No. 17, *Safety in the Transportation, Storage, Handling, and Use of Explosives.*

✷ ***Never*** prepare more primers than immediately needed.

✷ ***Never*** prepare primers in a magazine or near large quantities of explosive materials.

✷ ***Never*** slit, drop, twist, or tamp a primer.

3.5.1 Preparing a Primer

✷ ***Always*** insert the detonator completely into a hole in the explosive material made with a nonsparking punch designed for that purpose, or in the cap well of a manufactured booster.

✷ ***Always*** secure the detonator within the primer.

✷ ***Always*** point the detonator in the direction of the main explosive charge.

✷ ***Always*** secure the detonator to a booster cartridge so that no tension is placed on the cap wires, safety fuses, plastic tubing, or detonating cord at the point of entry into the detonator.

✷ ***Never*** use a cast primer or booster if the hole for the detonator is too small.

✷ ***Never*** enlarge a hole in a cast primer or booster to accept a detonator.

✷ ***Never*** punch explosive material that is very hard or frozen.

✷ ***Never*** force a detonator into explosive material.

3.5.2 Making Primers With Electric Detonators and Cartridged Explosives

Small-diameter cartridges (less than 4 inches, Figure 3.18):

1—Punch a hole straight into one end of cartridge.

2—Insert the detonator into the hole.

3—Tie leg wires around the cartridge using a half hitch. Never pull the wires too tightly because this may break them or damage the insulation.

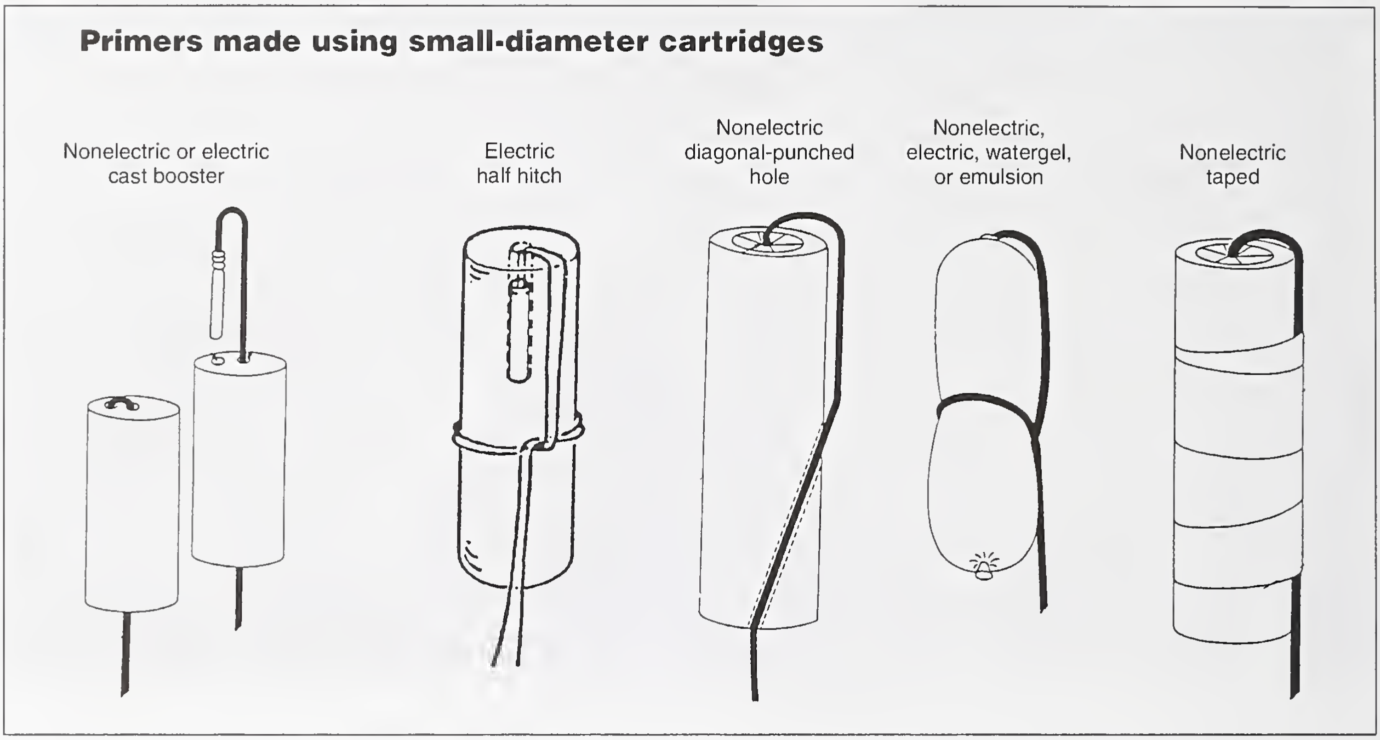


Figure 3.18—These primers use small-diameter cartridges. Some types may use detonating cord.

Large-diameter cartridges (4 inches or more, Figure 3.19):

1—Punch a slanting hole from the center of one end of the cartridge coming out 2 or more inches from the end.

2—Fold over the leg wires to form a sharp bend about 12 inches from the detonator.

3—Push the folded wires through the hole starting at the end of the cartridge and coming out through the side.

4—Open the folded wires and pass the loop over the other end of the cartridge.

5—Punch another hole straight into the end of the cartridge beside the first. Insert the detonator in this hole and take up all the slack in the wires.

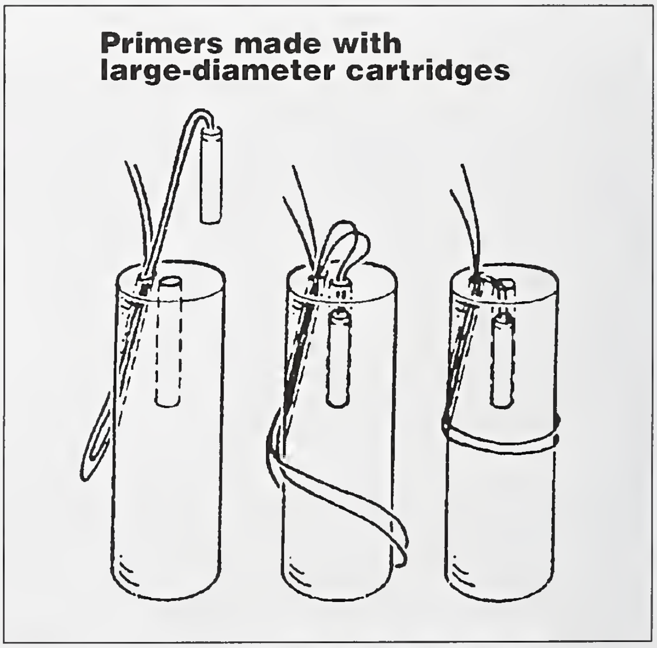


Figure 3.19—Primers made with large-diameter cartridges.

3.6 Remote-Detonating System

For many blasting activities, the Blaster and all personnel must move at least 500 feet (152 m) from an explosion. Under some circumstances this distance may be inconvenient, unsafe, or impractical. Airborne debris from large blasts such as those for waterfowl potholes may require Blasters to be half a mile (790 m) away. Deploying and reeling up wire for large distances can be extremely time consuming. The chance of open circuits increases in rough terrain.

A radio-controlled detonating system is available for blasting operations that eliminates the need for long lead wires that generally stretch 500 feet (152 m) between the Blaster-in-Charge and the explosives charge.

The system is capable of detonating electric blasting caps, exploding-bridgewire detonators, or nonelectric detonators. The system can be activated and controlled with a King radio that has been retrofitted with a *dual-tone modulation frequency* (DTMF) chip. The receiving system, called the Osprey 500E, can be placed as close as 10 feet (3 m) to the blast, depending on blast configuration [for fireline explosives or small surface loads less than 11 pounds (5 kg)]. The receiving system may also be placed up to 100 feet (31 m) away from the blast when initiating EBW's and any distance away when initiating electric or nonelectric blasting caps. If needed, the system can initiate electric or nonelectric detonators from 500 feet (152 m) in the same manner as any initiating device.

The entire remote-detonating system allows the Blaster-in-Charge more flexibility in selecting a location to initiate the blast and in selecting the type of detonator. Blasting operations can be more efficient because there is no wire between the radio and receiver. In addition, blasting operations are safer because:

* The system does not arm itself until the Blaster-in-Charge switches the key on and waits 2 minutes, which is generally enough time for the Blaster-in-Charge to reach a safe area.

* The system shuts itself down automatically 20 minutes after being switched on and it cannot be rearmed remotely.

* All guards can listen to the sequence. They have the ability to stop the sequence by pushing the number *0* on their King radio (provided it has the DTMF chip).

* Wire does not restrict the location where the Blaster-in-Charge can initiate the blast, allowing the safest areas to be used.

* There is less chance for misfires due to short circuits and broken wires.

Configurations—The following configurations are available for the remote detonation system:

Configuration No. 1: Electric blasting cap (Figure 3.20)

Remote-detonating system with standard electric blasting cap

Figure 3.20—Remote-detonating system configured with standard electric blasting cap.

Configuration No. 2: EBW detonator (Figure 3.21)

Configuration No. 3: Nonelectric detonation (Figure 3.22).

Description—The remote-detonation system includes the following components:

* Receiver/controller (Osprey 500E.)

* Transmitter radio with DTMF module.

* EBW adapter (power multiplier).

* Nonelectric detonator adapter.

* Connecting wire, detonators, or nonelectric trunkline.

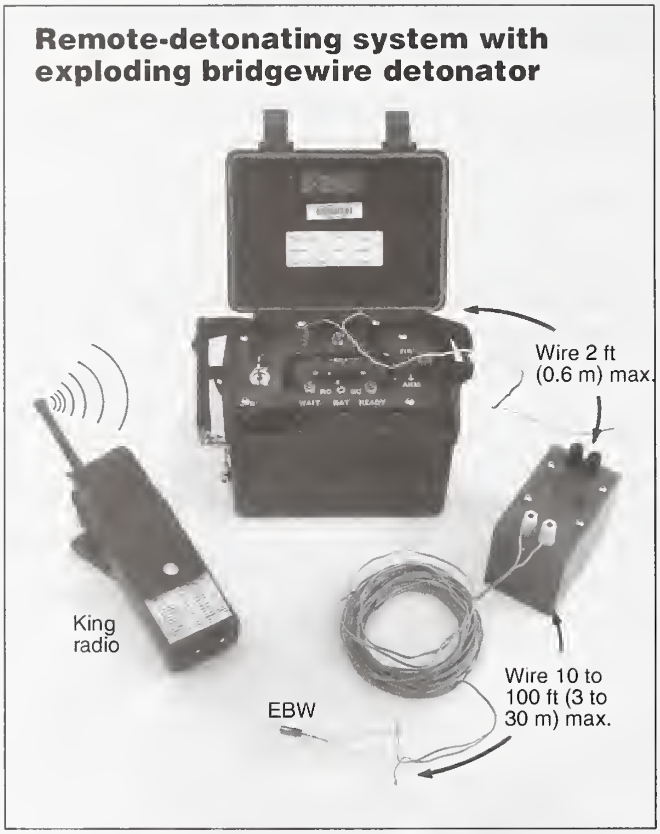


Figure 3.21—Remote-detonating system configured with an EBW.

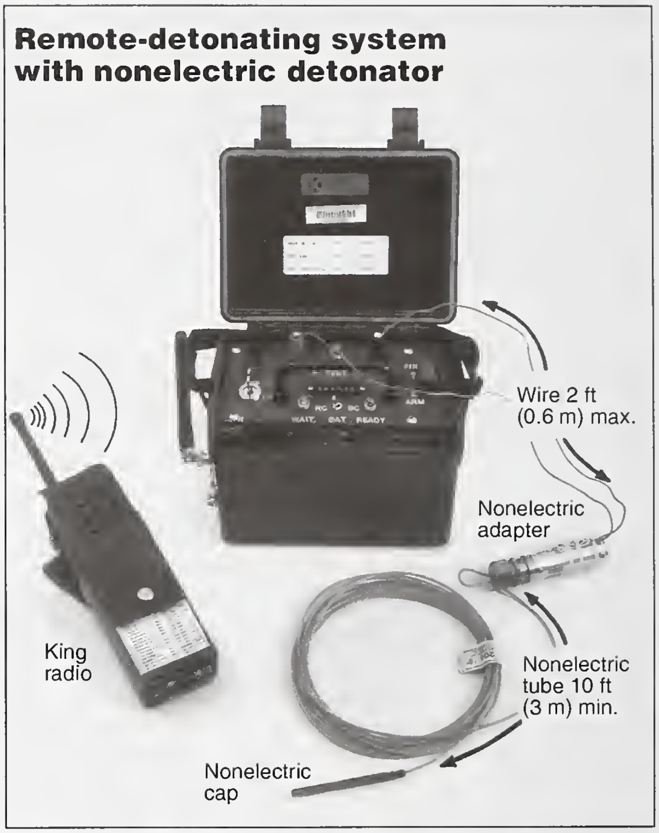


Figure 3.22—Remote-detonating system using a nonelectric cap.

The receiver/controller weighs 9 pounds (about 4 kg). It is contained in a plastic weatherproof box measuring 6 by 7.5 by 9 inches (15 by 19 by 23 cm) and consists of:

* Programmable VHF scanner with antenna for receiving radio signals.
* Circuitry for decoding and processing the signal.
* Safety and timing circuitry.
* Power output circuitry for detonators or other devices.
* Manual arm-and-fire switch.
* Control switches and indicator lights.
* Sixteen C-batteries.

Preparations—Operators of the new remote-detonating system must determine the frequencies that will be most commonly used and program the scanner in the receiver controller for those frequencies. All unused channels must be blocked out so that only the frequencies that are being used are scanned. A radio technician on most Forest units can provide this information and assist in the programming. Be sure to lock out the keyboard before reassembling the receiver/controller.

The operator must determine if the King radio being used has a dual-tone modulation frequency chip. These chips are available from most Forest Service radio technicians.

Check all new units to ensure that the batteries have been installed correctly and test each of the two circuits with a voltmeter in accordance with the manufacturer's instructions. Connect the voltmeter to the (+) and (-) test pins and move the RC and BC switch to each position.

Turn the key to the *On* position and be sure that the wait light turns on. Make sure that the ready light turns on about 2 minutes later. Conduct a dry run, pushing the appropriate key code on the King radio, and observe that the *Arm* light illuminates after sending all six code numbers. After about 20 minutes the system will shut down. Be sure to turn the key to the *Off* position when the system is not in use.

Perform several dry runs with the remote-detonating system to become familiar with all of the functions and characteristics of each configuration. Select a numbering sequence that can be remembered and that is convenient to use with the coded thumb wheels.

Firing Sequence—The following firing sequence is recommended:

1—Explosives are deployed and guards are moved to appropriate locations.

2—Receive/controller and selected adapter are placed no closer than 10 feet (3 meters) to the explosives charge and up to 100 feet (30 meters) or more away from the explosives charge depending on the configuration.

3—Appropriate adapter is wired to the receiver controller (EBW or nonelectric) and shotshell primer is installed in the nonelectric adapter (Figure 3.23).

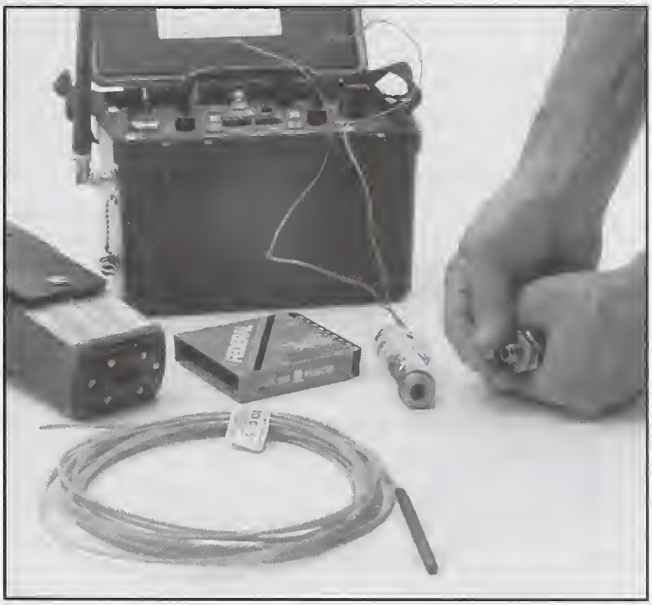


Figure 3.23—Nonelectric adapter.

4—Shunted detonator wire or nonelectric trunkline is laid out between adapter and explosives.

5—Blaster-in-Charge checks the continuity of the wiring and checks for stray current, if using electric blasting caps.

6—Blaster-in-Charge connects the detonator to the circuit or trunkline and checks with the guards (*Blasting One* or the first *Fire-in-the-Hole* call).

7—Blaster-in-Charge inserts the detonator into the explosives and returns to the receiver/controller.

8—Blaster-in-Charge connects the wire or trunkline into the appropriate adapter and checks with the guards (*Blasting Two* or the second *Fire-in-the-Hole* call).

9—Blaster-in-Charge inserts the key, switches the receiver controller on, and notes the time (2 minutes until the machine is ready).

10—Blaster-in-Charge moves to a safe area and checks with the guards just before transmitting the detonation code (*Blasting Now* or final *Fire-in-the-Hole* call).

11—Blaster-in-Charge depresses the *Send* button on the radio, transmits the first five digits of the coded sequence to the receiver, then releases the *Send* button.

12—After waiting 15 seconds for the receiver controller to arm, the final digit is transmitted to fire the shot.

13—After the shot fires, the Blaster-in-Charge checks and clears the area.

Misfires—If there is a misfire, the Blaster-in-Charge must notify the guards and try:

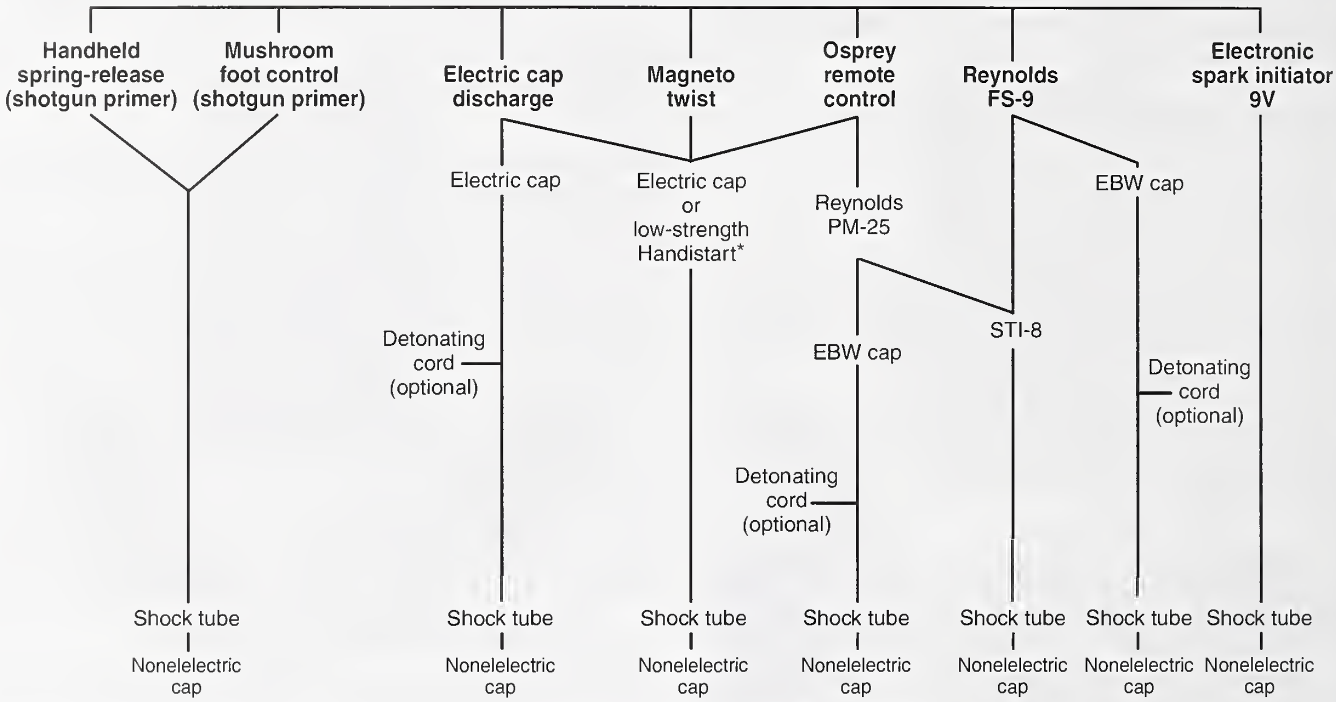
* Transmitting the sequence a second time.
* Transmitting the sequence with the radio switched from low to high.
* Replacing the batteries in the radio and retransmitting.

If the shot does not fire, the Blaster-in-Charge must wait for the receiver/controller to shut down (approximately 20 minutes) before moving to the receiver. The waiting time is not necessary if EBW's are being used.

Troubleshooting—Check the system for the following signs of trouble:

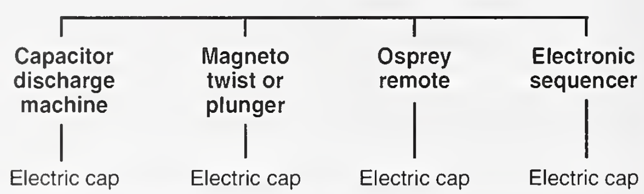
* Wires are shorted, touching, or broken.
* Batteries in the receiver/controller are low or are not installed properly.
* Volume and squelch are not adjusted correctly on the scanner in the receiver/controller (see the manufacturer's instructions).
* Scanner keypad is not locked (the programming will be erased when the unit is reassembled).
* Excess channels are not locked out on the scanner.
* The scanner is not programmed properly (wrong channels in radios).
* Bad detonator (a rare occurrence).

Nonelectric Initiation Paths

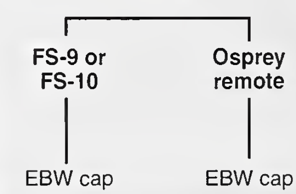


* NOTE: ***Do Not Use*** detonating cord with Handistarts.

EBC Initiation Path



EBW Initiation Path



Chapter 4—Storage

4.1 General

Storage shall conform to Title 27 CFR, Part 55, Subpart K, Storage (of BATF). Exceptions, other than more stringent regulations of local, State, and Federal agencies, shall be approved by the Director of BATF (see ATF P 5400.7) dated 6/90.

For inspection and recordkeeping, see Sections 1.2 and 1.3 of Chapter 1. Keep duplicate records of the magazine inventory at the office as well as in the magazine.

4.2 Storing Explosives in Remote, Uninhabited, and Roadless Locations

In remote, uninhabited, and roadless locations (backcountry or wilderness), store explosives and detonators separately behind natural barriers in an area out of sight and a safe distance from the trail. Make them as secure from theft as possible. Clear away leaves, dead grass, and other flammable materials. Protect explosives from water with fire-resistant waterproof material, such as a tarpaulin or fire-shelter material. Slope the ground to keep surface water away. Post explosives with a red-on-white warning sign reading, *Explosives, Keep Off* in letters at least 1½ inches (3.81 cm) high. Place the warning sign on or against the explosives, but not where it is in view from the trail.

Transport only enough explosives to the work area for one work period, 5 or 10 days. Never leave explosives unattended for more than 12 hours. Where practical, transport portable magazines by plane or helicopter. Maintain an inventory of explosives stored in the backcountry just as you would for any magazine.

4.3 Storing Fireline Explosives in the Field (Wildfire)

Use portable Type 2 magazines where possible (27 CFR §55.203). A Type 3 magazine or an explosives transport truck may be used if storage distance and attendance regulations are adhered to and the truck is kept locked (27 CFR §55.205 and §55.208).

When it is not possible to store explosives in an approved magazine, store the explosives in a secured area away from camp. If possible, store explosives behind a natural or manmade barrier. Cover the explosives with a fire-resistant waterproof material, such as a tarp or fire-shelter material. The explosives shall be under constant surveillance by a guard. Post the explosives with clearly visible red-on-white warning signs reading, *Explosives, Keep Off.* Never store detonators with the fireline explosives. In the event of a lightning storm, move all personnel, including the guard, at least 1,000 feet from the storage area.

When in a spike camp away from roads, explosives may be stored as in Section 4.2, *only when absolutely necessary.*

4.4 Two-Component Explosives

An approved magazine for storing two-component explosives is a locked cabinet for each component. However, when mixed they become a Class A (1.1D) explosive and must be stored according to 27 CFR §55.203.

4.5 Permanent Magazines

Post magazines sites with signs reading *Danger–Never Fight Explosives Fires* (Figure 4.1). Locate signs to minimize the possibility of a bullet traveling in the direction of the magazine if anyone shoots at the sign. Post a sign at access points reading *Danger—Explosives. In an emergency, call (a phone number that can be reached 24 hours a day).* Day boxes shall not be used for permanent storage.

DANGER!
NEVER fight explosives fires!

Explosives are stored on this site.
Phone________________ (daytime)
or ________________ (night)

Figure 4.1—Post all entrances to magazines with signs.

4.5.1 Code of Federal Regulations (27 CFR Part 55, Subpart K)

Bureau of Alcohol, Tobacco, and Firearms
(Department of Treasury)

27 CFR Part 55, Subpart K—Storage

§ 55.201 General.

(a) Section 842(j) of the Act and § 55.29 of this part require that the storage of explosive materials by any person must be in accordance with the regulations in this part. Further, section 846 of this Act authorizes regulations to prevent the recurrence of accidental explosions in which explosive materials were involved. The storage standards prescribed by this subpart confer no right or privileges to store explosive materials in a manner contrary to State or local law

(b) The Director may authorize alternate construction for explosives storage magazines when it is shown that the alternate magazine construction is substantially equivalent to the standards of safety and security contained in this subpart. Any alternate explosive magazine construction approved by the Director prior to August 9, 1982, will continue as approved unless notified in writing by the Director. Any person intending to use alternate magazine construction shall submit a letter application to the regional director (compliance) for transmittal to the Director, specifically describing the proposed magazine. Explosive materials may not be stored in alternate magazines before the applicant has been notified that the application has been approved.

(c) A licensee or permittee who intends to make changes in his magazines, or who intends to construct or acquire additional magazines, shall comply with § 55.63.

(d) The regulations set forth in §§ 55.221 through 55.224 pertain to the storage of special fireworks, pyrotechnic compositions and explosive materials used in assembling fireworks.

(e) The provisions of §55.202(a) classifying flash powder and bulk salutes as high explosives are mandatory after March 7, 1990: *Provided,* that those persons who hold licenses or permits under this part on that date shall, with respect to the premises covered by such licenses or permits, comply with the high explosives storage requirements for flash powder and bulk salutes by March 7, 1991. [T.D. ATF–87, 46 FR 40384, Aug. 7, 1981, as amended by T.D. ATF–293, 55 FR 3722, Feb. 5, 1990]

§ 55.202 Classes of explosive materials.

For purposes of this part, there are three classes of explosive materials. These classes, together with the description of explosive materials comprising each class, are as follows:

(a) *High explosives.* Explosive materials which can be caused to detonate by means of a blasting cap when unconfined, (for example, dynamite, flash powders, and bulk salutes). See also § 55.201(e).

27 CFR Part 55, Subpart K—Storage *(continued)*

(b) *Low explosives.* Explosive materials which can be caused to deflagrate when confined, (for example, black powder, safety fuses, igniters, igniter cords, fuse lighters, and "special fireworks" defined as Class B explosives by U.S. Department of Transportation regulations in 49 CFR part 173, except for bulk salutes).

(c) *Blasting agents.* (For example, ammonium nitrate-fuel oil and certain watergels (see also § 55.11). [T.D. ATF–87, 46 FR 40384, Aug. 7, 1981, as amended by T.D. ATF–293, 55 FR 3722, Feb. 5, 1990]

§ 55.203 Types of magazines.

For purposes of this part, there are five types of magazines. These types, together with the classes of explosive materials, as defined in § 55.202, which will be stored in them, are as follows:

(a) *Type 1 magazines.* Permanent magazines for the storage of high explosives, subject to the limitations prescribed by §§ 55.206 and 55.213. Other classes of explosive materials may also be stored in type 1 magazines.

(b) *Type 2 magazines.* Mobile and portable indoor and outdoor magazines for the storage of high explosives, subject to the limitations prescribed by §§ 55.206, 55.208(b), and 55.213. Other classes of explosive materials may also be stored in type 2 magazines.

(c) *Type 3 magazines.* Portable outdoor magazines for the temporary storage of high explosives while attended (for example, a "day box"), subject to the limitations prescribed by §§ 55.206 and 55.213. Other classes of explosives materials may also be stored in type 3 magazines.

(d) *Type 4 magazines.* Magazines for the storage of low explosives, subject to the limitations prescribed by §§ 55.206(b), 55.210(b), and 55.213. Blasting agents may be stored in type 4 magazines, subject to the limitations prescribed by §§ 55.206(c), 55.211(b), and 55.213. Detonators that will not mass detonate may also be stored in type 4 magazines, subject to the limitations prescribed by §§ 55.206(a), 55.210(b), and 55.213.

(e) *Type 5 magazines.* Magazines for the storage of blasting agents, subject to the limitations prescribed by §§ 55.206 (c), 55.211(b), and 55.213.

§ 55.204 Inspection of magazines.

Any person storing explosive materials shall inspect his magazines at least every seven days. This inspection need not be an inventory,

27 CFR Part 55, Subpart K—Storage *(continued)*

but must be sufficient to determine whether there has been unauthorized entry or attempted entry into the magazines, or unauthorized removal of the contents of the magazines.

§ 55.205 Movement of explosive materials.

All explosive materials must be kept in locked magazines meeting the standards in this subpart unless they are:

(a) In the process of manufacture;

(b) Being physically handled in the operating process of a licensee or user;

(c) Being used; or

(d) Being transported to a place of storage or use by a licensee or permittee or by a person who has lawfully acquired explosive materials under § 55.106.

§ 55.206 Location of magazines.

(a) Outdoor magazines in which high explosives are stored must be located no closer to inhabited buildings, passenger railways, public highways, or other magazines in which high explosives are stored, than the minimum distances specified in the table of distances for storage of explosive materials in § 55.218.

(b) Outdoor magazines in which low explosives are stored must be located no closer to inhibited buildings, passenger railways, public highways, or other magazines in which explosive materials are stored, than the minimum distances specified in the table of distances for storage of low explosives in § 55.219, except that the table of distances in § 55.224 shall apply to the storage of special fireworks. The distances shown in § 55.219 may not be reduced by the presence of barricades.

(c)(1) Outdoor magazines in which blasting agents in quantities of more than 50 pounds are stored must be located no closer to inhabited buildings, passenger railways, or public highways than the minimum distances specified in the table of distances for storage of explosive materials in § 55.218.

(2) Ammonium nitrate and magazines in which blasting agents are stored must be located no closer to magazines in which high explosives or other blasting agents are stored than the minimum distances specified in the table of distances for the separation of ammonium nitrate and blasting agents in § 55.220. However, the minimum distances for magazines in which explosives and blasting agents are stored from inhabited buildings, etc., may not be less than the distances specified in the table of distances for storage of explosives materials in § 55.218. [T.D. ATF–87, 46 FR 40384, Aug. 7, 1981, as amended by T.D. ATF–293, 55 FR 3722, Feb. 5, 1990]

27 CFR Part 55, Subpart K—Storage *(continued)*

§ 55.207 Construction of type 1 magazines.

A type 1 magazine is a permanent structure: a building, an igloo or "Army-type structure," a tunnel, or a dugout. It is to be bullet-resistant, fire-resistant, weather-resistant, theft-resistant, and ventilated.

(a*) Buildings.* All building type magazines are to be constructed of masonry, wood, metal, or a combination of these materials, and have no openings except for entrances and ventilation. The ground around building magazines must slope away for drainage or other adequate drainage provided.

(1) *Masonry wall construction.* Masonry wall construction is to consist of brick, concrete, tile, cement block, or cinder block and be not less than 6 inches in thickness. Hollow masonry units used in construction must have all hollow spaces filled with well-tamped, coarse, dry sand or weak concrete (at least a mixture of one part cement and eight parts of sand with enough water to dampen the mixture while tamping in place). Interior walls are to be constructed of, or covered with, a nonsparking material.

(2*) Fabricated metal wall construction.* Metal wall construction is to consist of sectional sheets of steel or aluminum not less than number 14-gauge, securely fastened to a metal framework. Metal wall construction is either lined inside with brick, solid cement blocks, hardwood not less than four inches thick, or will have at least a six inch sand fill between interior and exterior walls. Interior walls are to be constructed of, or covered with, a nonsparking material.

(3) *Wood frame wall construction.* The exterior of outer wood walls is to be covered with iron or aluminum not less than number 26-gauge. An inner wall of, or covered with nonsparking material will be constructed so as to provide a space of not less than six inches between the outer and inner walls. The space is to be filled with coarse, dry sand or weak concrete.

(4) *Floors.* Floors are to be constructed of, or covered with, a nonsparking material and shall be strong enough to bear the weight of the maximum quantity to be stored. Use of pallets covered with a nonsparking material is considered equivalent to a floor constructed of or covered with a nonsparking material.

(5) *Foundations.* Foundations are to be constructed of brick, concrete, cement block, stone, or wood posts. If piers or posts are used, in lieu of a continuous foundation, the space under the buildings is to be enclosed with metal.

(6) *Roof.* Except for buildings with fabricated metal roofs, the outer roof is to be covered with no less than number 26-guage iron or aluminum, fastened to at least $\frac{7}{8}$-inch sheathing.

(7) *Bullet-resistant ceilings or roofs.* Where it is possible for a bullet to be fired directly through the roof and into the magazine at such an angle that the bullet would strike the explosives within, the magazine is to be protected by one of the following methods:

(i) A sand tray lined with a layer of building paper, plastic, or other nonporous material, and filled with not less than four inches of coarse, dry sand, and located at the tops of inner walls covering the entire ceiling area, except that portion necessary for ventilation.

(ii) A fabricated metal roof constructed of $\frac{3}{16}$-inch plate steel lined with four inches of hardwood. (For each additional $\frac{1}{16}$ inch of plate steel, the hardwood lining may be decreased one inch.)

27 CFR Part 55, Subpart K—Storage *(continued)*

(8) *Doors.* All doors are to be constructed of not less than ¼-inch plate steel and lined with at least two inches of hardwood. Hinges and hasps are to be attached to the doors by welding, riveting or bolting (nuts on inside of door). They are to be installed in such a manner that the hinges and hasps cannot be removed when the doors are closed and locked.

(9) *Locks.* Each door is to be equipped with:

(i) two mortise locks;
(ii) two padlocks fastened in separate hasps and staples;
(iii) a combination of a mortise lock and a padlock;
(iv) a mortise lock that requires two keys to open; or
(v) a three-point lock.

Padlocks must have at least five tumblers and a case-hardened shackle of at least ⅜-inch diameter. Padlocks must be protected with not less than ¼-inch steel hoods constructed so as to prevent sawing or lever action on the locks, hasps, and staples. These requirements do not apply to magazine doors that are adequately secured on the inside by means of a bolt, lock, or bar that cannot be actuated from the outside.

(10) *Ventilation.* Ventilation is to be provided to prevent dampness and heating of stored explosive materials. Ventilation openings must be screened to prevent the entrance of sparks. Ventilation openings in side walls and foundations must be offset or shielded for bullet-resistant purposes. Magazines having foundation and roof ventilators with the air circulating between the side walls and the floors and between the side walls and the ceiling must have a wooden lattice lining or equivalent to prevent the packages of explosive materials from being stacked against the side walls and blocking the air circulation.

(11) *Exposed metal.* No sparking material is to be exposed to contact with the stored explosive materials. All ferrous metal nails in the floor and side walls, which might be exposed to contact with explosive materials, must be blind nailed, countersunk, or covered with a nonsparking lattice work or other nonsparking material.

(b) *Igloos, "Army-type" structures, tunnels, and dugouts.* Igloo, Army-type structure, tunnel, and dugout magazines are to be constructed of reinforced concrete, masonry, metal, or a combination of these materials. They must have an earthmound covering of not less than 24 inches on the top, sides and rear unless the magazine meets the requirements of paragraph (a)(7) of this section. Interior walls and floors must be constructed of, or covered with, a nonsparking material. Magazines of this type are also to be constructed in conformity with the requirements of paragraph (a)(4) and paragraphs (a)(8) through (11) of this section.

§ 55.208 Construction of type 2 magazines.

A type 2 magazine is a box, trailer, semitrailer, or other mobile facility.

(a) *Outdoor magazines*

(1) *General.* Outdoor magazines are to be bullet-resistant, fire-resistant, weather-resistant, theft-resistant, and ventilated. They are to be supported to prevent direct contact with the ground and,

27 CFR Part 55, Subpart K—Storage *(continued)*

if less than one cubic yard in size, must be securely fastened to a fixed object. The ground around outdoor magazines must slope away for drainage or other adequate drainage provided. When unattended, vehicular magazines must have wheels removed or otherwise effectively immobilized by kingpin locking devices or other methods approved by the Director.

(2) *Exterior construction.* The exterior and doors are to be constructed of not less than ¼-inch steel and lined with at least two inches of hardwood. Magazines with top openings will have lids with water-resistant seals or which overlap the sides by at least one inch when in a closed position.

(3) *Hinges and hasps.* Hinges and hasps are to be attached to doors by welding, riveting, or bolting (nuts on inside of door). Hinges and hasps must be installed so that they cannot be removed when the doors are closed and locked.

(4) *Locks.* Each door is to be equipped with

(i) two mortise locks;
(ii) two padlocks fastened in separate hasps and staples;
(iii) a combination of a mortise lock and a padlock;
(iv) a mortise lock that requires two keys to open; or
(v) a three-point lock.

Padlocks must have at least five tumblers and a case-hardened shackle of at least ⅜-inch diameter. Padlocks must be protected with not less than ¼-inch steel hoods constructed so as to prevent sawing or lever action on the locks, hasps, and staples. These requirements do not apply to magazine doors that are adequately secured on the inside by means of a bolt, lock, or bar that cannot be actuated from the outside.

(b) *Indoor magazines.*

(1) *General.* Indoor magazines are to be fire-resistant and theft-resistant. They need not be bullet-resistant and weather-resistant if the buildings in which they are stored provide protection from the weather and from bullet penetration. No indoor magazine is to be located in a residence or dwelling. The indoor storage of high explosives must not exceed a quantity of 50 pounds. More than one indoor magazine may be located in the same building if the total quantity of explosive materials stored does not exceed 50 pounds. Detonators must be stored in a separate magazine (except as provided in § 55.213) and the total quantity of detonators must not exceed 5,000.

(2) *Exterior construction.* Indoor magazines are to be constructed of wood or metal according to one of the following specifications:

(i) Wood indoor magazines are to have sides, bottoms and doors constructed of at least two inches of hardwood and are to be well braced at the corners. They are to be covered with sheet metal of not less than number 26 gauge (0.0179 inches). Nails exposed to the interior of magazines must be countersunk.

(ii) Metal indoor magazines are to have sides, bottoms and doors constructed of not less than number 12-gauge (0.1046-inch) metal and be lined inside with a nonsparking material. Edges of metal covers must overlap sides at least one inch.

(3) *Hinges and hasps.* Hinges and hasps are to be attached to doors by welding, riveting, or bolting (nuts on inside of door). Hinges and hasps must be installed so that they cannot be removed when the doors are closed and locked.

27 CFR Part 55, Subpart K—Storage *(continued)*

(4) *Locks.* Each door is to be equipped with:
(i) two mortise locks;
(ii) two padlocks fastened in separate hasps and staples;
(iii) a combination of a mortise lock and a padlock;
(iv) a mortise lock that requires two keys to open; or
(v) a three-point lock.
Padlocks must have at least five tumblers and a case-hardened shackle of at least ⅜-inch diameter. Padlocks must be protected with not less than ¼-inch steel hoods constructed so as to prevent sawing or lever action on the locks, hasps, and staples. Indoor magazines located in secure rooms that are locked as provided in this subparagraph may have each door locked with one steel padlock (which need not be protected by a steel hood) having at least five tumblers and a case-hardened shackle of at least ⅜-inch diameter, if the door hinges and lock hasp are securely fastened to the magazine. These requirements do not apply to magazine doors that are adequately secured on the inside by means of a bolt, lock, or bar that cannot be actuated from the outside.

(c) *Detonator boxes.* Magazines for detonators in quantities of 100 or less are to have sides, bottoms and doors constructed of not less than number 12-gauge (0.1046-inch) metal and lined with a nonsparking material. Hinges and hasps must be attached so they cannot be removed from the outside. One steel padlock (which need not be protected by a steel hood) having at least five tumblers and a case-hardened shackle of at least ⅜-inch diameter is sufficient for locking purposes.

§ 55.209 Construction of type 3 magazines.

A type 3 magazine is a "day box" or other portable magazine. It must be fire-resistant, weather-resistant, and theft-resistant. A type 3 magazine is to be constructed of not less than number 12-gauge (0.1046-inch) steel, lined with at least either ½-inch plywood or ½-inch Masonite-type hardboard. Doors must overlap sides by at least one inch. Hinges and hasps are to be attached by welding, riveting or bolting (nuts on inside). One steel padlock (which need not be protected by a steel hood) having at least five tumblers and a case-hardened shackle of at least ⅜-inch diameter is sufficient for locking purposes. Explosive materials are not to be left unattended in type 3 magazines and must be removed to type 1 or 2 magazines for unattended storage.

§ 55.210 Construction of type 4 magazines.

A type 4 magazine is a building, igloo or "Army-type structure," tunnel, dugout, box, trailer, or a semitrailer or other mobile magazine.

(a) *Outdoor magazines.*
(1) *General.* Outdoor magazines are to be fire-resistant, weather-resistant, and theft-resistant. The ground around outdoor magazines must slope away for drainage or other adequate drainage

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be provided. When unattended, vehicular magazines must have wheels removed or otherwise be effectively immobilized by kingpin locking devices or other methods approved by the Director.
(2) *Construction.* Outdoor magazines are to be constructed of masonry, metal-covered wood, fabricated metal, or a combination of these materials. Foundations are to be constructed of brick, concrete, cement block, stone, or metal or wood posts. If piers or posts are used, in lieu of a continuous foundation, the space under the building is to be enclosed with fire-resistant material. The walls and floors are to be constructed of, or covered with, a nonsparking material or lattice work. The doors must be metal or solid wood covered with metal.
(3) *Hinges and hasps.* Hinges and hasps are to be attached to doors by welding, riveting, or bolting (nuts on inside of door). Hinges and hasps must be installed so that they cannot be removed when the doors are closed and locked.
(4) *Locks.* Each door is to be equipped with:
(i) two mortise locks;
(ii) two padlocks fastened in separate hasps and staples;
(iii) a combination of a mortise lock and a padlock;
(iv) a mortise lock that requires two keys to open; or
(v) a three-point lock.
Padlocks must have at least five tumblers and case-hardened shackle of at least ⅜-inch diameter. Padlocks must be protected with not less than ¼-inch steel hoods constructed so as to prevent sawing or lever action on the locks, hasps, and staples. These requirements do not apply to magazine doors that are adequately secured on the inside by means of a bolt, lock, or bar that cannot be actuated from the outside.

(b) *Indoor magazine.*
(1) *General.* Indoor magazines are to be fire-resistant and theft-resistant. They need not be weather-resistant if the buildings in which they are stored provide protection from the weather. No indoor magazine is to be located in a residence or dwelling. The indoor storage of low explosives must not exceed a quantity of 50 pounds. More than one indoor magazine may be located in the same building if the total quantity of explosive materials stored does not exceed 50 pounds. Detonators that will not mass detonate must be stored in a separate magazine and the total number of electric detonators must not exceed 5,000.
(2) *Construction.* Indoor magazines are to be constructed of masonry, metal-covered wood, fabricated metal, or a combination of these materials. The walls and floors are to be constructed of, or covered with, a nonsparking material. The doors must be metal or solid wood covered with metal.
(3) *Hinges and hasps.* Hinges and hasps are to be attached to doors by welding, riveting, or bolting (nuts on inside of door). Hinges and hasps must be installed so that they cannot be removed when the doors are closed and locked.
(4) *Locks.* Each door is to be equipped with:
(i) two mortise locks;
(ii) two padlocks fastened in separate hasps and staples;
(iii) a combination of a mortise lock and padlock;
(iv) a mortise lock that requires two keys to open; or
(v) a three-point lock.
Padlocks must have at least five tumblers and a case-hardened shackle of at least ⅜-inch diameter. Padlocks must be protected

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with not less than $\frac{1}{4}$-inch steel hoods constructed so as to prevent sawing or lever action on the locks, hasps, and staples. Indoor magazines located in secure rooms that are locked as provided in this subparagraph may have each door locked with one steel padlock (which need not be protected by a steel hood) having at least five tumblers and a case-hardened shackle of at least $\frac{3}{8}$-inch diameter, if the door hinges and lock hasp are securely fastened to the magazine. These requirements do not apply to magazine doors that are adequately secured on the inside by means of a bolt, lock, or bar that cannot be actuated from the outside.

§ 55.211 Construction of type 5 magazines.

A type 5 magazine is a building, igloo or "Army-type" structure,tunnel, dugout, bin, box, trailer, or a semitrailer or other mobile facility.

(a) *Outdoor magazines.*

(1) *General.* Outdoor magazines are to be weather-resistant and theft-resistant. The ground around magazines must slope away for drainage or other adequate drainage be provided. When unattended, vehicular magazines must have wheels removed or otherwise be effectively immobilized by kingpin locking devices or other methods approved by the Director.

(2) *Construction.* The doors are to be constructed of solid wood or metal.

(3) *Hinges and hasps.* Hinges and hasps are to be attached to doors by welding, riveting, or bolting (nuts on inside of door). Hinges and hasps must be installed so that they cannot be removed when the doors are closed and locked.

(4) *Locks.* Each door is to be equipped with:

(i) two mortise locks;
(ii) two padlocks fastened in separate hasps and staples;
(iii) a combination of a mortise lock and a padlock;
(iv) a mortise lock that requires two keys to open; or
(v) a three-point lock.

Padlocks must have at least five tumblers and a case-hardened shackle of at least $\frac{3}{8}$-inch diameter. Padlocks must be protected with not less than $\frac{1}{4}$-inch steel hoods constructed so as to prevent sawing or lever action on the locks, hasps, and staples. Trailers, semitrailers, and similar vehicular magazines may, for each door, be locked with one steel padlock (which need not be protected by a steel hood) having at least five tumblers and a case-hardened shackle of at least $\frac{3}{8}$-inch diameter, if the door hinges and lock hasp are securely fastened to the magazine and to the door frame. These requirements do not apply to magazine doors that are adequately secured on the inside by means Bureau of Alcohol, Tobacco and Firearms, Treasury § 55.214 of a bolt, lock, or bar that cannot be actuated from the outside.

(5) *Placards.* The placards required by Department of Transportation regulations at 49 CFR part 172, Subpart F, for the transportation of blasting agents shall be displayed on all magazines.

(b) *Indoor magazines.*

(1) *General.* Indoor magazines are to be theft-resistant. They need not be weather-resistant if the buildings in which they are

27 CFR Part 55, Subpart K—Storage *(continued)*

stored provide protection from the weather. No indoor magazine is to be located in a residence or dwelling. Indoor magazines containing quantities of blasting agents in excess of 50 pounds are subject to the requirements of § 55.206 of this subpart.

(2) *Construction.* The doors are to be constructed of wood or metal.

(3) *Hinges and hasps.* Hinges and hasps are to be attached to doors by welding, riveting, or bolting (nuts on inside). Hinges and hasps must be installed so that they cannot be removed when the doors are closed and locked.

(4) *Locks.* Each door is to be equipped with:

(i) two mortise locks;
(ii) two padlocks fastened in separate hasps and staples;
(iii) a combination of a mortise lock and a padlock;
(iv) a mortise lock that requires two keys to open; or
(v) a three-point lock.

Padlocks must have at least five tumblers and a case-hardened shackle of at least $\frac{3}{8}$-inch diameter. Padlocks must be protected with not less than $\frac{1}{4}$-inch steel hoods constructed so as to prevent sawing or lever action on the locks, hasps, and staples. Indoor magazines located in secure rooms that are locked as provided in this subparagraph may have each door locked with one steel padlock (which need not be protected by a steel hood) having at least five tumblers and a case-hardened shackle of at least $\frac{3}{8}$-inch diameter, if the door hinges and lock hasps are securely fastened to the magazine and to the door frame. These requirements do not apply to magazine doors that are adequately secured on the inside by means of a bolt, lock, or bar that cannot be actuated from the outside. [T.D. ATF–87, 46 FR 40384, Aug. 7, 1981, as amended by T.D. ATF–298, 55 FR 21863, May 30, 1990]

§ 55.212 Smoking and open flames.

Smoking, matches, open flames, and spark producing devices are not permitted:

(a) In any magazine;

(b) Within 50 feet of any outdoor magazine; or

(c) Within any room containing an indoor magazine.

§ 55.213 Quantity and storage restrictions.

(a) Explosive materials in excess of 300,000 pounds or detonators in excess of 20 million are not to be stored in one magazine unless approved by the Director.

(b) Detonators are not to be stored in the same magazine with other explosive materials, except under the following circumstances:

(1) In a type 4 magazine, detonators that will not mass detonate

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may be stored with electric squibs, safety fuse, igniters, and igniter cord.

(2) In a type 1 or type 2 magazine, detonators may be stored with delay devices and any of the items listed in paragraph (b)(1) of this section.

§ 55.214 Storage within types 1, 2, 3, and 4 magazines.

(a) Explosive materials within a magazine are not to be placed directly against interior walls and must be stored so as not to interfere with ventilation. To prevent contact of stored explosive materials with walls, a nonsparking lattice work or other nonsparking material may be used.

(b) Containers of explosive materials are to be stored so that marks are visible. Stocks of explosive materials are to be stored so they can be easily counted and checked upon inspection.

(c) Except with respect to fiberboard or other nonmetal containers, containers of explosive materials are not to be unpacked or repacked inside a magazine or within 50 feet of a magazine, and must not be unpacked or repacked close to other explosive materials. Containers of explosive materials must be closed while being stored.

(d) Tools used for opening or closing containers of explosive materials are to be of nonsparking materials, except that metal slitters may be used for opening fiberboard containers. A wood wedge and a fiber, rubber, or wooden mallet are to be used for opening or closing wood containers of explosive materials. Metal tools other than nonsparking transfer conveyors are not to be stored in any magazine containing high explosives.

§ 55.215 Housekeeping.

Magazines are to be kept clean, dry, and free of grit, paper, empty packages and containers, and rubbish. Floors are to be regularly swept. Brooms and other utensils used in the cleaning and maintenance of magazines must have no spark-producing metal parts, and may be kept in magazines. Floors stained by leakage from explosive materials are to be cleaned according to instructions of the explosives manufacturer. When any explosive material has deteriorated it is to be destroyed in accordance with the advice or instructions of the manufacturer. The area surrounding magazines is to be kept clear of rubbish, brush, dry grass, or trees (except live trees more than 10 feet tall), for not less than 25 feet in all directions. Volatile materials are to be kept a distance of not less than 50 feet from outdoor magazines. Living foliage which is used to stabilize the earthen covering of a magazine need not be removed.

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§ 55.216 Repair of magazines.

Before repairing the interior of magazines, all explosive materials are to be removed and the interior cleaned. Before repairing the exterior of magazines, all explosive materials must be removed if there exists any possibility that repairs may produce sparks or flame. Explosive materials removed from magazines under repair must be:

(a) placed in other magazines appropriate for the storage of those explosive materials under this subpart, or

(b) placed a safe distance from the magazines under repair where they are to be properly guarded and protected until the repairs have been completed.

§ 55.217 Lighting.

(a) Battery-activated safety lights or battery-activated safety lanterns may be used in explosives storage magazines.

(b) Electric lighting used in any explosives storage magazine must meet the standards prescribed by the *National Electrical Code,* (National Fire Protection Association, NFPA 70–81), for the conditions present in the magazine at any time. All electrical switches are to be located outside of the magazine and also meet the standards prescribed by the National Electrical Code.

(c) Copies of invoices, work orders or similar documents which indicate the lighting complies with the *National Electrical Code* must be available for inspection by ATF officers.

§ 55.218 Table of distances for storage of explosive materials.

27 CFR Part 55, Subpart K—Storage *(continued)*

§ 55.218 Table of distances for storage of explosive materials.

QUANTITY OF EXPLOSIVES		DISTANCES IN FEET							
		Inhabited buildings		Public highways Class A to D		Passenger railways—public highways with traffic volume of more than 3,000 vehicles a day		Separation of magazines	
Pounds over	Pounds not over	Barricaded	Unbarricaded	Barricaded	Unbarricaded	Barricaded	Unbarricaded	Barricaded	Unbarricaded
2	5	70	140	30	60	51	102	6	12
5	10	90	180	35	70	64	128	8	16
10	20	110	220	45	90	81	162	10	20
20	30	125	250	50	100	93	186	1	22
30	40	140	280	55	110	103	206	12	24
40	50	150	300	60	120	110	220	14	28
50	75	170	340	70	140	12	254	15	30
75	100	190	380	75	150	139	278	16	32
100	125	200	400	80	160	150	300	18	36
125	150	215	430	85	170	159	318	19	38
150	200	235	470	95	190	175	350	21	42
200	250	255	510	105	210	189	378	23	46
250	300	270	540	110	220	201	402	24	48
300	400	295	590	120	240	221	442	27	54
400	500	320	640	130	260	238	476	29	58
500	600	340	680	135	270	253	506	31	62
600	700	355	710	145	290	266	532	32	64
700	800	375	750	150	300	278	556	33	66
800	900	390	780	155	310	289	578	35	70
900	1,000	400	800	160	320	300	600	36	72
1,000	1,200	425	850	165	330	318	636	39	78
1,200	1,400	450	900	170	340	336	672	41	82
1,400	1,600	470	940	175	350	351	702	43	86
1,600	1,800	490	980	180	360	366	732	44	88
1,800	2,000	505	1,010	185	370	378	756	45	90
2,000	2,500	545	1,090	190	380	408	816	49	98
2,500	3,000	580	1,160	195	390	432	864	52	104
3,000	4,000	635	1,270	210	420	474	948	58	116
4,000	5,000	685	1,370	225	450	513	1,026	61	122
5,000	6,000	730	1,460	235	470	546	1,092	65	130
6,000	7,000	770	1,540	245	490	573	1,146	68	136
7,000	8,000	800	1,600	250	500	600	1,200	72	144
8,000	9,000	835	1,670	255	510	624	1,248	75	150
9,000	10,000	865	1,730	260	520	645	1,290	78	156
10,000	12,000	875	1,750	270	540	687	1,374	82	164
12,000	14,000	885	1,770	275	550	723	1,446	87	174
14,000	16,000	900	1,800	280	560	756	1,512	90	180
16,000	18,000	940	1,880	285	570	786	1,572	94	188
18,000	20,000	975	1,950	290	580	813	1,626	98	196
20,000	25,000	1,055	2,000	315	630	876	1,752	105	210
25,000	30,000	1,130	2,000	340	680	933	1,866	112	224
30,000	35,000	1,205	2,000	360	720	981	1,962	119	238
35,000	40,000	1,275	2,000	380	760	1,026	2,000	124	248
40,000	45,000	1,340	2,000	400	800	1,068	2,000	129	258
45,000	50,000	1,400	2,000	420	840	1,104	2,000	135	270
50,000	55,000	1,460	2,000	440	880	1,140	2,000	140	280
55,000	60,000	1,515	2,000	455	910	1,173	2,000	145	290
60,000	65,000	1,565	2,000	470	940	1,206	2,000	150	300
65,000	70,000	1,610	2,000	485	970	1,236	2,000	155	310
70,000	75,000	1,655	2,000	500	1,000	1,263	2,000	160	320
75,000	80,000	1,695	2,000	510	1,020	1,293	2,000	165	330
80,000	85,000	1,730	2,000	520	1,040	1,317	2,000	170	340
85,000	90,000	1,760	2,000	530	1,060	1,344	2,000	175	350
90,000	95,000	1,790	2,000	540	1,080	1,368	2,000	180	360
95,000	100,000	1,815	2,000	545	1,090	1,392	2,000	185	370
100,000	110,000	1,835	2,000	550	1,100	1,437	2,000	195	390
110,000	120,000	1,855	2,000	555	1,110	1,479	2,000	205	410
120,000	130,000	1,875	2,000	560	1,120	1,521	2,000	215	430
130,000	140,000	1,890	2,000	565	1,130	1,557	2,000	225	450
140,000	150,000	1,900	2,000	570	1,140	1,593	2,000	235	470
150,000	160,000	1,935	2,000	580	1,160	1,629	2,000	245	490
160,000	170,000	1,965	2,000	590	1,180	1,662	2,000	255	510
170,000	180,000	1,990	2,000	600	1,200	1,695	2,000	265	530
180,000	190,000	2,010	2,010	605	1,210	1,725	2,000	275	550
190,000	200,000	2,030	2,030	610	1,220	1,755	2,000	285	570
200,000	210,000	2,055	2,055	620	1,240	1,782	2,000	295	590
210,000	230,000	2,100	2,100	635	1,270	1,836	2,000	315	630
230,000	250,000	2,155	2,155	650	1,300	1,890	2,000	335	670
250,000	275,000	2,215	2,215	670	1,340	1,950	2,000	360	720
275,000	300,000	2,275	2,275	690	1,380	2,000	2,000	385	770

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§ 55.219 American table of distances for storage of explosives (December 1910), as revised and approved by the Institute of Makers of Explosives—November 5, 1971.

Notes to the Table of Distances for Storage of Explosives:

(1) Terms found in the table of distances for storage of explosive materials are defined in § 55.11.

(2) When two or more storage magazines are located on the same property, each magazine must comply with the minimum distances specified from inhabited buildings, railways, and highways, and, in addition, they should be separated from each other by not less than the distances shown for *Separation of Magazines,* except that the quantity of explosives contained in cap magazines shall govern in regard to the spacing of said cap magazines from magazines containing other explosives. If any two or more magazines are separated from each other by less than the specified *Separation of Magazines,* and the total quantity of explosives stored in such group must be treated as if stored in a single magazine located on the site of any magazine of the group, and must comply with the minimum of distances specified from other magazines, inhabited buildings, railways, and highways.

(3) All types of blasting caps in strengths through No. 8 cap should be rated at 1½ lbs. of explosives per 1,000 caps. For strengths higher than No. 8 cap, consult the manufacturer.

(4) For quantity and distance purposes, detonating cord of 50 or 60 grains per foot should be calculated as equivalent to 9 lbs. of high explosives per 1,000 feet. Heavier or lighter core loads should be rated proportionately.

§ 55.219 Table of distances for storage of explosives

Pounds		Distance from inhabited building (feet)	Distance from railroad/ highway (feet)	From above-ground magazine (feet)
Over	Not over			
0	1,000	75	75	50
1,000	5,000	115	115	75
5,000	10,000	150	150	100
10,000	20,000	190	190	125
20,000	30,000	215	215	145
30,000	40,000	235	235	155
40,000	50,000	250	250	165
50,000	60,000	260	260	175
60,000	70,000	270	270	185
70,000	80,000	280	280	190
80,000	90,000	295	295	195
90,000	100,000	300	300	200
100,000	200,000	375	375	250
200,000	300,000	450	450	300

§ 55.220 Table of separation distances of ammonium nitrate and blasting agents from explosives or blasting agents. Table: Department of Defense Ammunition and Explosives Standards, Table 5-4.1 Extract; 4145.27 M, March 1969

27 CFR Part 55, Subpart K—Storage *(continued)*

Donor weight (pounds)		Minimum separation distance of acceptor from donor when barricaded (feet)		Minimum thickness of artificial barricades (inches)
Over	Not over	Ammonium nitrate	Blasting agent	
–	100	3	11	12
100	300	4	14	12
300	600	5	18	12
600	1,000	6	22	12
1,000	1,600	7	25	12
1,600	2,000	8	29	12
2,000	3,000	9	32	15
3,000	4,000	10	36	15
4,000	6,000	11	40	15
6,000	8,000	12	43	20
8,000	10,000	13	47	20
10,000	12,000	14	50	20
12,000	16,000	15	54	25
16,000	20,000	16	58	25
20,000	25,000	18	65	25
25,000	30,000	19	68	30
30,000	35,000	20	72	30
35,000	40,000	21	76	30
40,000	45,000	22	79	35
45,000	50,000	23	83	35
50,000	55,000	24	86	35
55,000	60,000	25	90	35
60,000	70,000	26	94	40
70,000	80,000	28	101	40
80,000	90,000	30	108	40
90,000	100,000	32	115	40
100,000	120,000	34	122	50
120,000	140,000	37	133	50
140,000	160,000	40	144	50
160,000	180,000	44	158	50
180,000	200,000	48	173	50
200,000	220,000	52	187	60
220,000	250,000	56	202	60
250,000	275,000	60	216	60
275,000	300,000	64	230	60

Table: National Fire Protection Association (NFPA) Official Standard No. 492, 1968.

Notes of Table of Separation Distances of Ammonium Nitrate and Blasting Agents From Explosives or Blasting Agents:

(1) This table specifies separation distances to prevent explosion of ammonium nitrate and ammonium nitrate-based blasting agents by propagation from nearby stores of high explosives or blasting agents referred to in the table as the "donor." Ammonium nitrate, by itself, is not considered to be a donor when applying this table. Ammonium nitrate, ammonium-nitrate fuel oil or combinations thereof are acceptors. If stores of ammonium nitrate are located within the sympathetic detonation distance of explosives or blasting agents, one-half the mass of the ammonium nitrate is to be included in the mass of the donor.

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(2) When the ammonium nitrate and/or blasting agent is not barricaded, the distances shown in the table must be multiplied by six. These distances allow for the possibility of high velocity metal fragments from mixers, hoppers, truck bodies, sheet metal structures, metal containers, and the like which may enclose the "donor." Where explosives storage is in bullet-resistant magazines or where the storage is protected by a bullet-resistant wall, distances and barricade thicknesses in excess of those prescribed in the table in § 55.218 are not required.

(3) These distances apply to ammonium nitrate that passes the insensitivity test prescribed in the definition of ammonium nitrate fertilizer issued by the Fertilizer Institute. [1]Ammonium nitrate failing to pass the test must be stored at separation distances in accordance with the table in § 55.218.

(4) These distances apply to blasting agents which pass the insensitivity test prescribed in regulations of the U.S. Department of Transportation (49 CFR part 173).

(5) Earth or sand dikes, or enclosures filled with the prescribed minimum thickness of earth or sand are acceptable artificial barricades. Natural barricades, such as hills or timber of sufficient density that the surrounding exposures which require protection cannot be seen from the "donor" when the trees are bare of leaves, are also acceptable.

(6) For determining the distances to be maintained from inhabited buildings, passenger railways, and public highways, use the table in § 55.218.

§ 55.221 Requirements for special fireworks, pyrotechnic compositions, and explosive materials used in assembling fireworks.

(a) Special fireworks, pyrotechnic compositions and explosive materials used to assemble fireworks shall be stored at all times as required by this subpart unless they are in the process of manufacture, assembly, packaging, or are being transported.

(b) No more than 500 pounds (227 kg) of pyrotechnic compositions or explosive materials are permitted at one time in any fireworks mixing building, any building or area in which the pyrotechnic compositions or explosive materials are pressed or otherwise prepared for finishing or assembly, or any finishing or assembly building. All pyrotechnic compositions or explosive materials not in immediate use will be stored in covered, nonferrous containers.

(c) The maximum quantity of flash powder permitted in any fireworks process building is 10 pounds (4.5 kg).

(d) All dry explosive powders and mixtures, partially assembled special fireworks, and finished special fireworks shall be removed from fireworks process buildings at the conclusion of a day's operations and placed in approved magazines. [T.D. ATF–293, 55 FR 3722, Feb. 5, 1990]

[1]Definition and Test Procedures for Ammonium Nitrate Fertilizer, Fertilizer Institute, 1015–28th St. N.W., Washington, DC 20036.

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§ 55.222 Table of distances between fireworks process buildings and between fireworks process and fireworks nonprocess buildings.

Net weight of fireworks[1] (pounds)	Special fireworks[2] (feet)	Common fireworks[3] (feet)
0 to 100	57	37
101 to 200	69	37
201 to 300	77	37
301 to 400	85	37
401 to 500	91	37
Above 500	Not permitted [4,5]	Not permitted [4,5]

[1]Net weight is the weight of all pyrotechnic compositions, and explosive materials and fuse only.
[2]The distances in this column apply only with natural or artificial barricades. If such barricades are not used, the distances must be doubled.
[3]While common fireworks in a finished state are not subject to regulation, explosive materials used to manufacture or assemble such fireworks are subject to regulation. Thus, fireworks process buildings where common fireworks are being processed must meet these requirements.
[4]A maximum of 500 pounds of inprocess pyrotechnic compositions, either loose or in partially-assembled fireworks, is permitted in any fireworks process building. Finished special fireworks may not be stored in a fireworks process building.
[5]A maximum of 10 pounds of flash powder, either in loose form or in assembled units, is permitted in any fireworks process building. Quantities in excess of 10 pounds must be kept in an approved magazine. [T.D. ATF–293, 55 FR 3723, Feb. 5, 1990] 27 CFR Ch. I (4-1-98 Edition)

§ 55.223 Table of distances between fireworks process buildings and other specified areas.

Distance from passenger railways, public highways, fireworks-plant buildings used to store common fireworks, magazines and fireworks-shipping buildings, and inhabited buildings[3,4].

Net weight of fireworks[1] (pounds)	Special fireworks[2] (feet)	Common fireworks[3] (feet)
0 to 100	200	25
101 to 200	200	50
201 to 300	200	50
301 to 400	200	50
401 to 500	200	50
Above 500	Not permitted	Not permitted

[1]Net weight is the weight of all pyrotechnic compositions, and explosive materials and fuse only.
[2]While common fireworks in a finished state are not subject to regulation, explosive materials used to manufacture or assemble such fireworks are subject to regulation. Thus, fireworks process

27 CFR Part 55, Subpart K—Storage *(continued)*

buildings where common fireworks are being processed must meet these requirements.
[3]This table does not apply to the separation distances between fireworks process buildings (see § 55.222) and between magazines (see §§ 55.218 and 55.224).
[4]The distances in this table apply with or without artificial or natural barricades or screen barricades. However, the use of barricades is highly recommended. [T.D. ATF–293, 55 FR 3723, Feb. 5, 1990]

§ 55.224 Table of distances for the storage of special fireworks (except bulk salutes).

Net weight of fireworks[1] (pounds)	Distance between magazine[2] and inhabited building, passenger railway, or public highway[3,4] (feet)	Distance between magazines[2] (feet)
0 to 1,000	150	100
1,001 to 5,000	230	150
5,001 to 10,000	300	200
Above 10,000	Use table § 55.218	—

[1]Net weight is the weight of all pyrotechnic compositions, and explosive materials and fuse only.
[2]For the purposes of applying this table, the term "magazine" also includes fireworks shipping buildings for special fireworks.
[3]For fireworks storage magazines in use prior to (30 days from the date of publication of the final rule in the Federal Register), the distances in this table may be halved if properly barricaded between the magazine and potential receptor sites.
[4]This table does not apply to the storage of bulk salutes. Use table at § 55.218. [T.D. ATF–293, 55 FR 3723, Feb. 5, 1990]

Chapter 5—Transportation

5.1 General

Explosives pose risks to health, safety, and property during transportation. Special requirements have been developed for transporting various types of explosives by motor vehicle, watercraft, rail, and aircraft.

In general, shipments of explosives shall comply with the Code of Federal Regulations (CFR 49) and State and local (municipal) laws. Other regulations may also need to be addressed, such as those of the United States Coast Guard, and port and harbor authorities, where applicable.

5.2 Transporting Explosives by Motor Vehicles

5.2.1 Operator Requirements

Vehicle operators must hold a valid commercial driver's license (CDL) with a hazardous-materials endorsement in accordance with 49 CFR, Part 383 and must be qualified operators in accordance with 49 CFR, Part 391.

Vehicle operators must be familiar with the traffic regulations and state laws governing the transportation of explosives. This certified individual must remain in or near the vehicle at all times.

When transporting explosives or any hazardous material, it must be properly and accurately described on the shipping papers in accordance with 49 CFR, Part 172, Subpart C *Shipping Papers* and those papers shall be readily available in the vehicle.

When the driver is at the vehicle's controls, the documents shall be:

- In immediate reach while the driver is restrained by safety belts; and

- Either readily visible to a person entering the driver's compartment or in a holder mounted to the inside of the door on the driver's side of the vehicle.

When the driver is not at the vehicle's controls, the shipping papers shall be:

- In a holder mounted to the inside of the door on the driver's side of the vehicle; or

- On the driver's seat in the vehicle.

The following documents must be in possession of the driver:

- Emergency Response Information as required by 49 CFR, Part 172, Subpart G. The document must contain, as a minimum, the following information:

  –Basic description and technical name.

  –Immediate hazard to health.

  –Risks of fire or explosion.

  –Immediate precautions to be taken in the event of an accident or incident.

  –Immediate methods for handling fires.

  –Initial methods for handling spills or leaks in the absence of fire.

  –Preliminary first aid measures; and

  –An emergency response phone number.

A copy of the appropriate page for the North American Emergency Response Guidebook or a properly completed Material Safety Data Sheet may be attached to the shipping papers to meet this requirement.

- Proper shipping papers for hazardous materials (Figure 5.1).

- A written route plan for the transportation of explosives.

- A copy of 49 CFR Part 397, Transportation of Hazardous Materials; Driving and Parking Rules, Federal Motor Carrier Safety Regulations (following pages).

- Obtain State explosive and hazardous materials transportation permits, if applicable.

EXPLOSIVES & HAZARDOUS MATERIALS
- Bill of Lading -

Date: Permit# Expires:

Agency:

Address:

City: State:

Phone: Driver Name:

Transport From: To:

Route Plan:

EMERGENCY

If in danger of fire, evacuate area. If cargo is burning, evacuate to one mile for 1.1, 1.2, 1.3, 1.5, and 1.6, class A or B. Evacuate to 1/3 mile for 1.4 class C. DON'T FIGHT FIRE!

FOR CHEMICAL EMERGENCY

(Accident, Spill, Exposure or Leak)
Call CHEMTREC, day or night at:
1-800-424-9300

For Agency Certified Blaster Call:
( ) ______________

NUMBER OF PACKAGES	NUMBER OF UNITS	PROPER SHIPPING NAME AND HAZARD CLASS	EMERGENCY RESPONSE PROCEDURE GUIDE NO.	WEIGHT (Subject to correction)
		BOOSTERS, 1.1D, UN00042, PGII	112	
		CORD, DETONATING, 1.1D, UN0065, PGII	112	
		EXPLOSIVE, BLASTING TYPE A, 1.1D, UN0081, PGII	112	
		EXPLOSIVE BLASTING, TYPE E, 1.1D, UN0241, PGII	112	
		DETONATORS, ELECTRIC, 1.1B, UN0030, PGII	112	
		DETONATOR ASSEMBLIES, NON-ELECTRIC, 1.1B, UN0360, PGII	112	
		DETONATOR ASSEMBLIES, NON-ELECTRIC, 1.4B, UN0361, PGII	114	
		DETONATORS, ELECTRIC, 1.4B, UN0255, PGII	114	
		DETONATORS, NON-ELECTRIC, 1.4S, UN0455, PGII	114	
		CORD, DETONATING, 1.4D, UN0289, PGII	114	
		EXPLOSIVE, BLASTING, TYPE B, 1.5D, UNO331, PGII	112	
		EXPLOSIVE, BLASTING, TYPE E, 1.5D, UN0332, PGII	112	
		AMMONIUM NITRATE-FUEL OIL MIXTURE, 1.5D, NA0331, PGII	140	
		ARTICLES, EXPLOSIVES, n.o.s., 1.4S, UN0349, PGII (CONTAINS: HMX, ALUMINUM POWDER)	114	
		ARTICLES, EXPLOSIVES, n.o.s., 1.4B, UNO350, PGII	114	
		NITROMENTHANE, LTD. QTY., CLASS 3, UN1261, PGII	129	
		AMMONIUM NITRATE, LTD. QTY., CLASS 5.1, UN1942, PGIII	140	

PLACARDS APPLIED TO VEHICLE

- ☐ NONE REQUIRED
- ☐ EXPLOSIVES 1.1
- ☐ EXPLOSIVES 1.4
- ☐ EXPLOSIVES 1.5 BLASTING AGENT
- ☐ DANGEROUS

TOTALS

Packages ________

Weight ________ Lbs.

This is to certify that the above-named materials are properly described and are in proper condition for transportation, according to the applicable regulations of the U.S. Department of Transportation.

Driver Signature ______________________

Figure 5.1—*Explosives and Hazardous Materials Bill of Lading* form.

49 CFR Part 397—Transportation of Hazardous Materials: Driving and Parking Rules

AUTHORITY: 49 USC App. §§1801-1813 (1982 and Supp III 1985); 49 CFR 1.48.

§397.1 Application of the rules in this part.

(a) Except as provided In paragraph (c) of this section, the rules in this part apply to each motor carrier engaged in the transportation of hazardous materials by a motor vehicle which must be marked or placarded in accordance with §177.823 of this title and to:
(1) Each officer or employee of the carrier who performs supervisory duties related to the transportation of hazardous materials; and
(2) Each person who operates or who is in charge of a motor vehicle containing hazardous materials.

(b) Each person designated in paragraph (a) of this section must know and obey the rules in this part.

§397.2 Compliance with Federal motor-carrier safety regulations.

A motor carrier or other person to whom this part is applicable must comply with the rules in Parts 390 through 397, inclusive, of this subchapter when he is transporting hazardous materials by a motor vehicle which must be marked or placarded in accordance with §177.823 of this title.

49 CFR Part 397—Transportation of Hazardous Materials: Driving and Parking Rules *(continued)*

§397.3 State and local laws, ordinances, and regulations.

Every motor vehicle containing hazardous materials must be driven and parked in compliance with the laws, ordinances, and regulations of the jurisdiction in which it is being operated, unless they are at variance with specific regulations of the Department of Transportation which are applicable to the operation of that vehicle and which impose a more stringent obligation or restraint.

§397.5 Attendance and surveillance of motor vehicles.

(a) Except as provided in paragraph (b) of this section, a motor vehicle which contains Class A or B explosives must be attended at all times by its driver or a qualified representative of the motor carrier that operates it.

(b) The rules In paragraph (a) of this section do not apply to a motor vehicle which contains Class A of B explosives if all the following conditions exist:
(1) The vehicle is located on the property of a motor carrier, on the property of a shipper or consignee of the explosives, in a safe haven, or in the case of a vehicle containing 50 pounds or less of either Class A or B explosives, on a construction or survey site; and
(2) The lawful bailee of the explosives is aware of the nature of the explosives the vehicle contains and has been instructed in the procedures he must follow in emergencies; and
(3) The vehicle is within the bailee's unobstructed field of view, or is located in a safe haven.

(c) A motor vehicle which contains hazardous materials other than Class A or B explosives and which is located on a public street or highway or the shoulder of a public highway must be attended by its driver. However, the vehicle need not be attended while its driver is performing duties which are incident and necessary to his duties as the operator of the vehicle.

(d) For purposes of this section:
(1) A motor vehicle is attended when the person in charge of the vehicle is on the vehicle, awake, and not in a sleeper berth, or is within 100 feet of the vehicle and has it within his unobstructed field of view.
(2) A qualified representative of a motor carrier is a person who:
(i) Has been designated by the carrier to attend the vehicle.
(ii) Is aware of the nature of the hazardous materials contained in the vehicle he attends.
(iii) Has been instructed in the procedures he must follow in emergencies; and
(iv) Is authorized to move the vehicle and has the means and ability to do so.
(3) A safe haven is an area specifically approved in writing by local, State, or Federal governmental authorities for the parking of unattended vehicles containing Class A or B explosives.

(e) The rules In this section do not relieve a driver from any obligation imposed by law relating to the placing of warning devices when a motor vehicle is stopped on a public street or highway.

49 CFR Part 397—Transportation of Hazardous Materials: Driving and Parking Rules *(continued)*

§3977 Parking.

(a) A motor vehicle which contains Class A or B explosives must not be parked under any of the following circumstances:
(1) On or within 5 feet of the traveled portion of a public street or highway;
(2) On a private property (including premises of a fueling or eating facility) without the knowledge and consent of the person who is in charge of the property and who is aware of the nature of the hazardous materials the vehicle contains; or
(3) Within 300 feet of a bridge, tunnel, dwelling, building, or place where people work, congregate, or assemble, except for brief periods when the necessities of operation require the vehicle to be parked and make it impracticable to park the vehicle in any other place.

§397.9 Routes.

(a) Unless there is no practicable alternative, a motor vehicle which contains hazardous materials must be operated over routes which do not go through or near heavily populated areas, places where crowds are assembled, tunnels, narrow streets, or alleys. Operating convenience is not a basis for determining whether it is practicable to operate a motor vehicle in accordance with this paragraph. This paragraph does not apply to radioactive materials (see §177.825 of this title).

(b) Before a motor carrier requires or permits a motor vehicle containing Class A or B explosives to be operated, he must prepare a written plan of a route that complies with the rules in paragraph (a) of this section for that vehicle and must furnish a copy of the written plan to the driver. However, the driver may prepare the written plan as agent for the motor carrier when the driver begins his trip at a location other than the carrier's terminal.

§397.11 Fires.

(a) A motor vehicle containing hazardous materials must not be operated near an open fire unless its driver has first taken precautions to ascertain that the vehicle can safely pass the fire without stopping.

(b) A motor vehicle containing hazardous materials must not be parked within 300 feet of an open fire.

§397.13 Smoking.

No person may smoke or carry a lighted cigarette, cigar, or pipe on or within 25 feet of:

(a) A motor vehicle which contains explosives, oxidizing materials, or flammable materials; or

49 CFR Part 397—Transportation of Hazardous Materials: Driving and Parking Rules *(continued)*

(b) An empty tank motor vehicle which has been used to transport flammable liquids or gases and which, when so used, was required to be marked or placarded in accordance with the rules in §177.823 of this title.

§397.15 Fueling.

When a motor vehicle which contains hazardous materials is being fueled:

(a) Its engine must not be operating; and

(b) A person must be in control of the fueling process at the point where the fuel tank is filled.

§397.17 Tires.

(a) If a motor vehicle which contains hazardous materials is equipped with dual tires on any axle, its driver must stop the vehicle in a safe location at least once during each 2 hours or 100 miles of travel, whichever is less, and must examine its tires. The driver must also examine the vehicle's tires at the beginning of each trip and each time the vehicle is parked.

(b) If as the result of an examination pursuant to paragraph (a) of this section, or otherwise, a tire is found to be flat, leaking, or improperly inflated, the driver must cause the tire to be repaired, replaced, or properly inflated before the vehicle Is driven. However, the vehicle may be driven to the nearest safe place to perform the required repair, replacement, or inflation.
(c) If as the result of an examination pursuant to paragraph (a) of this section, or otherwise, a tire is found to be overheated, the driver shall immediately cause the overheated tire to be removed and placed at a safe distance from the vehicle. The driver shall not operate the vehicle until the cause of the overheating is corrected.
(d) Compliance with the rules in this section does not relieve a driver from the duty to comply with the rules in §§397.5 and 397.7.

§397.19 Instructions and documents.

(a) A motor carrier that transports Class A or B explosives must furnish the driver of each motor vehicle in which the explosives are transported with the following documents:
(1) A copy of the rules in this part; and
(2) [Reserved].
(3) A document containing instructions on procedures to be followed in the event of accident or delay. The documents must include the names and telephone numbers of persons (including representatives of carriers or shippers) to be contacted, the nature of the explosives being transported, and the precautions to be taken in emergencies such as fires, accidents, or leakages.

> **49 CFR Part 397—Transportation of Hazardous Materials: Driving and Parking Rules** *(continued)*
>
> (b) A driver who receives documents in accordance with paragraph (a) of this section must sign a receipt for them. The carrier shall retain the receipt in his files for 1 year at his principal place of business. However, upon a written request to, and with the approval of, the Director, Regional Motor Carrier Safety Office, for the region In which a motor carrier has his principal place of business, the carrier may maintain the receipts at a regional or terminal office. The addresses and jurisdictions of the Directors of Regional Motor Carrier and Safety Offices are shown in §390.27 of this subchapter.
>
> (c) A driver of a motor vehicle which contain Class A or B explosives must be in possession of, be familiar with, and be in compliance with:
> (1) The documents specified in paragraph (a) of this section;
> (2) The documents specified in §177.817 of Chapter I of this title; and
> (3) The written route plan specified in §397.9(b).

Driving Safety

Trailers—Do not haul explosives in small single-axle utility trailers. If a trailer is required for equipment, attach with a positive grounding system. Use trailers only when needed for the job.

Division 1.1 or 1.2 explosives may not be loaded into or carried on any vehicles if:

* More than two cargo-carrying vehicles are in the combination;

* Any full trailer in the combination has a wheel base of less than 184 inches; and

* The other vehicle in the combination contains any initiating explosive.

Repair—Do not take motor vehicles carrying explosives, blasting agents, or blasting supplies inside a garage or shop for repairs or servicing.

Emergencies—In the event of breakdown or collision, secure the area and promptly notify the local fire and police departments for assistance.

Parking—Except in an emergency, do not park any vehicle transporting explosives—even though attended—on any public street adjacent to or in proximity to any bridge, tunnel, dwelling, building, or place where people work or assemble.

Railroad Grade Crossing—Any placarded vehicle, or one carrying any amount of chlorine, must stop at railroad crossings.

Stops must be made within 50 feet of the crossing, but no closer than 15 feet. Cross the tracks when it is safe to do so; do not shift gears while on the tracks.

Stops need not be made at:

* Streetcar crossings or industrial switching tracks within municipalities;

* Crossings where a police officer or flagman is directing traffic;

* Crossings which are marked by a stop-and-go traffic light which is green; and

* Abandoned rail lines and industrial or spur line crossings clearly marked *Exempt*.

Explosives Accidents—In the event of an accident involving any motor vehicle transporting any explosives, every available means shall be employed to prevent individuals, other than those employed in the protection of persons or property or in the removal of hazards or wreckage, from congregating in the vicinity. Such means shall also be employed to prevent smoking, to keep flame away, and to safeguard against the aggravation of the hazard present, and to warn other users of the highway. In the event that any motor vehicle laden with, or carrying dangerous explosives, is entangled with another or with any other object or structure following an accident, no attempt shall be made to disentangle either vehicle or the laden vehicle from the object or structure until the lading, together with any fragments thereof, be removed to a place at least 200 feet from the vehicle (and preferably 200 feet from any habitation). In the event of fire involving a motor vehicle laden with any explosive, every practical effort shall be made to give a warning of danger of explosion to habitants in the vicinity and to other users of the highway.

Emergency Signals (Stopped Vehicles)

* Turn signals: Whenever a motor vehicle is stopped upon the traveled portion of a highway or the shoulder of a highway for any cause other than necessary traffic stops, the driver of the stopped vehicle shall use the emergency flashers until warning devices are placed. The flashing signals shall be used during the time the warning devices are picked up for storage before moving of the vehicles. The flashing lights

may be used at other times while a vehicle is stopped in addition to, but not in lieu of, the warning devices in the section above.

* Placement of Warning Devices, General Rule: Except as provided in the section above, whenever a vehicle is stopped upon the traveled portion of a highway or the shoulder of a highway for any cause other than necessary traffic stops, the driver shall as soon as possible, but in any event within 10 minutes, place warning devices carried in the vehicle—either three emergency reflective triangles, three electric emergency lanterns, or three red emergency reflectors in the following manner:

–One at the traffic side of the stopped vehicle, within 10 feet of the front or rear of the vehicle.

–One at approximately 100 feet from the stopped vehicle in the center of the traffic lane or shoulder occupied by the vehicle and in a direction toward traffic approaching in that lane.

–One at approximately 500 feet from the stopped vehicle in the center of the traffic lane or shoulder occupied by the vehicle and a direction toward traffic approaching in that lane.

–One at approximately 100 feet from the stopped vehicle in the opposite direction from those placed in accordance with paragraph (a) and (b) of this section, in the center of the traffic lane or shoulder occupied by this vehicle.

* Special Rules—Business or Residential Districts: The placement of warning devices is not required within the business or residential district of a municipality, except during the time lighted lamps are required and when highway or street lighting is insufficient to make a vehicle clearly discernible at a distance of 500 feet to persons on the highway.

–Hills, Curves, and Obstructions: If a motor vehicle is stopped within 500 feet of a curve, crest of a hill, or other obstruction to view, the driver shall place warning devices in the direction of the obstruction to view by a distance of 100 feet to 500 feet from the stopped vehicle so as to afford ample warning to other users of the highway.

–Divided or One-Way Roads: If a motor vehicle is stopped upon the traveled portion or the shoulder of a divided or one-way highway, the driver shall place one warning device at a distance of 200 feet and one warning device at a distance of 100 feet in a direction toward approaching traffic in the center of the lane or shoulder occupied by the vehicle. The driver shall place one warning device at the traffic side of the vehicle within 10 feet of the rear of the vehicle.

–Emergency Signals, Flame-Producing: No driver shall attach or permit any person to attach a lighted fuse or other flame-producing emergency signal to any part of a motor vehicle transporting explosives.

–Emergency Signals, Dangerous Cargoes: No driver shall use or permit the use of any flame-producing emergency signal for protecting any motor vehicle transporting Division 1.1, 1.2, or 1.3 materials.

–Flame-Producing Devices Prohibited on Vehicles: Liquid-burning emergency flares, fusses, oil lanterns, or any signal produced by a flame shall not be carried on any motor vehicle transporting Division 1.1, 1.2, or 1.3 materials.

Delivery—Deliver explosives only to authorized persons and into approved magazines or approved temporary storage or handling areas. Do not park vehicle closer than 300 feet to buildings, bridges, tunnels, and personnel.

Other Safety Measures—Never smoke within 25 feet of a motor vehicle transporting explosives. Do not drive, load, or unload the vehicle in a careless or reckless manner.

Unless state laws are more restrictive, two persons are permitted to ride in a vehicle transporting explosives.

5.2.2 Hazardous Materials Training

Individuals who perform functions involved with the transportation of explosives must receive the minimum training in accordance with 49 CFR, Part 172, Subpart H. This training must include general awareness, function-specific safety training, and driver training. The retraining interval is set at every 3 years.

5.2.3 Vehicle Requirements

Condition—Thoroughly inspect all vehicles that transport explosives and correct all deficiencies before use (Figure

5.2). Vehicles, including engines, shall be clean, in good mechanical condition, and free of leaks. All safety equipment must be in good working order.

If vehicles do not have an enclosed bed, cover the bed with a flame- and moisture-proof tarpaulin or other effective protection against moisture and sparks. All vehicles transporting

DRIVER'S VEHICLE INSPECTION REPORT

(Per U.S. DOT Motor Carrier Safety Regs.)

PRELIMINARY, WALK-AROUND

- [ ] Windshield: clean, unbroken
- [ ] Lights: check all, including 4-way flashers
- [ ] Mirrors: clean, tight, unbroken
- [ ] Tires: good tread, proper inflation, good spare
- [ ] Fluid Leaks: check under vehicle
- [ ] Wipers: functional
- [ ] Wheels: lug nuts tight

INTERIOR CHECK

- [ ] Gauges: all working
- [ ] Horn: working
- [ ] Seat belts: functional
- [ ] Heater/Defroster: working

ENGINE COMPARTMENT

- [ ] Fluid Levels: check all
- [ ] Fan Belts: check for cracks, wear
- [ ] Hoses: check for leaks
- [ ] Battery, Electrical: check condition, look for loose wires
- [ ] Steering: excessive free-play, loose ball joints

MECHANICAL INSPECTION

- [ ] Driveline/U-joints: check for looseness
- [ ] Brakes: proper pedal adjustment, emergency brake holds
- [ ] Clutch: proper adjustment
- [ ] Suspension: check springs, shocks, and hangers

SAFETY EQUIPMENT

- [ ] Fire Extinguishers
- [ ] Emergency Reflector Kit
- [ ] First Aid Kit
- [ ] Spare Bulbs and Fuses
- [ ] 2-Way Radio/Cell Phone
- [ ] Proper Placards If Required
- [ ] Chock Blocks

OTHER ITEMS

- [ ] Tarp With Rope
- [ ] Tire Changing Tools
- [ ] Emergency Response Guide
- [ ] U.S. DOT Safety Regs.
- [ ] HazMat Bill Of Lading

Inspection Completed

Vehicle # ____________________

Odometer ____________________

Date: ____/____/____

Time: ___:___ am. ______ pm.

____
Driver Signature

Figure 5.2—*Driver's Vehicle Inspection Report* form.

explosives shall have tight floors. Cover any exposed spark-producing metal on the inside of the bed with wood or other nonsparking materials to prevent contact with explosive containers. Do not load explosives above the sides of an open-bed vehicle.

Secure any package containing explosives from moving while the vehicle is in motion.

Fire Extinguishers—Equip every motor vehicle used for transporting explosives with at least two 2A-10B:C or higher rated fire extinguishers. Securely mount the extinguishers near the driver for immediate access. Only extinguishers listed or approved by the Underwriter's Laboratories or Factory Mutual Liability Insurance Co. of America are suitable for use on vehicles transporting explosives (ratings are shown on the approved label).

Gross Weight Capacity—Vehicles shall be strong enough to carry the load without exceeding rated weight capacity.

Placarding—Placarding shall be in accordance with 49 CFR, Part 172.500, Subpart F, Placarding. Mark or placard vehicles transporting explosives on sides, front, and rear. When mixed loads are transported, display the placard for the most hazardous explosives (Figure 5.3).

Explosives placards shall be square on-point (diamond shape) and measure 10¾ inches on each side. The placards shall be orange with a white border; the symbol and print shall be black.

The vehicle does not require placards when transporting blasting caps (fuse-type or electric) in quantities of 1,000 or less, or just hazard Class 1.4, 1.5, or 1.6 explosives (blasting agents or Class C explosives) in quantities of 1,000 pounds (454 kg) or less.

Placards are not required when carrying 1,000 pounds or less of unmixed two-component explosives.

Other explosive materials in any quantity, such as dynamite, mixed two-component explosives, fireline explosives, primers, or avalanche ammunition will generally require *Explosives 1.1D* placards. However, it is up to the driver to determine what placard to use for the material being transported. This information can be obtained from the supplier and is also on the hazardous materials bill of lading.

5.2.4 Loading and Unloading

Load hazardous materials in accordance with Tables 5.1 and 5.2.

No explosives shall be loaded or unloaded from a vehicle with the engine running.

No bale hooks or other metal tools shall be used for the loading, unloading, or other handling of explosives. No package or other container of explosives, except barrels or kegs, shall be rolled. No packages of explosives shall be thrown or dropped during the process of loading, unloading, or handling. Special care shall be exercised to ensure that packages or other containers containing explosives shall not catch fire from sparks or hot gases from the vehicle exhaust or tailpipe.

5.2.5 Detonators

Exploding bridgewire detonators contain no primary explosives and therefore may be transported with other explosives when packaged in the original manufacturer's container provided they are labeled explosives 1.4 B or 1.4 S detonators (49 CFR, 173.63, p. 63, and 49 CFR 177.848).

Blasting caps, electric or fuse, contain a primary explosive and therefore may not be transported in the same vehicle with other explosives, unless packed in wooden or fiberboard boxes as per 49 CFR 173.63 and 173.68, and CFR 177.835. Boxes are in turn loaded into portable containers or separate compartments that meet the requirements of the Institute of Makers of Explosives IME-22 Standard (following pages). When electric blasting caps are carried in a vehicle equipped with a two-way radio, the transmitter must be turned off when caps are placed into or removed from the portable container.

General Guidelines on Use of Warning Labels and Placards

LABELS

See 49 CFR, Part 172, Subpart E for complete labeling regulations.

- Until October 1, 1993, all of the labels appearing on the Hazardous Materials Warning Labels chart may be used to satisfy the labeling requirements contained in Subpart E.
- On and after October 1, 1993, those labels in boxes marked "TRANSITION-2001" on the chart will not be authorized for use under Subpart E. (NOTE: these labels may be used IF they were affixed to a package offered for transportation and transported prior to October 1, 2001, and the package was filled with hazardous materials prior to October 1, 1991.)
- For classes 1,2,3,4,5,6 and 8, text indicating a hazard (e.g., "CORROSIVE") IS NOT required on a label. The label must otherwise conform to Subpart E [Section 172.405].
- Any person who offers a hazardous material for transportation MUST label the package, if required [Section 172.400(a)].
- The Hazardous Materials Table [Section 172.101] identifies the proper label(s) for the hazardous material listed.
- When required, labels must be printed on or affixed to the surface of the package near the proper shipping name [Section 172.406(a)].
- When two or more labels are required, they must be displayed next to each other [Section 172.406(c)].
- Labels may be affixed to packages when not required by regulations, provided each label represents a hazard of the material contained in the package [Section 172.401].

PLACARDS

See 49 CFR, Part 172, Subpart F for complete placarding regulations.

- All of the placards appearing on the Hazardous Materials Warning Placards chart may be used to satisfy the placarding requirements contained in Subpart F.
- Each person who offers for transportation or transports any hazardous material subject to the Hazardous Materials Regulations shall comply with all applicable requirements of Subpart F.
- Placards may be displayed for a hazardous material even when not required, if the placarding otherwise conforms to the requirements of Subpart F.
- For other than Class 7 or the OXYGEN placard, text indicating a hazard (e.g., "CORROSIVE") is not required on a placard [Section 172.519(b)].
- Any transport vehicle, freight container, or rail car containing any quantity of material listed in Table 1 (Section 172.504) must be placarded.
- When the gross weight of all hazardous materials covered in Table 2 is less than 454 kg (1,001 lbs), no placard is required on a transport vehicle or freight container [Section 172.504].

Effective October 1, 1994, and extending through October 1, 2001, these placards may be used for HIGHWAY TRANSPORTATION ONLY.

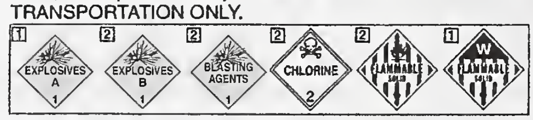


Illustration numbers in each square refer to Tables 1 and 2 below.

Poisonous Materials

§172.554

INHALATION HAZARD

§172.313

Materials which meet the inhalation toxicity criteria have additional "communication standards" prescribed by the HMR. First, the words "Poison-Inhalation Hazard" must be entered on the shipping paper, as required by Section 172.203(m)(3). Second, packagings must be marked "Inhalation Hazard" in accordance with Section 172.313(a). Lastly, transport vehicles, freight containers, portable tanks and unit load devices that contain a poisonous material subject to the "Poison-Inhalation Hazard" shipping description, must be placarded with a POISON or POISON GAS placard, as appropriate. This shall be in addition to any other placard required for that material in Section 172.504.

Table 1 (Placard any quantity)

Hazard class or division	Placard name
1.1	EXPLOSIVES 1.1
1.2	EXPLOSIVES 1.2
1.3	EXPLOSIVES 1.3
2.3	POISON GAS
4.3	DANGEROUS WHEN WET
6.1 (PGI, PIH only)	POISON
7 (Radioactive Yellow III)	RADIOACTIVE

Table 2 (Placard 1,001 pounds or more)

1.4	EXPLOSIVES 1.4
1.5	EXPLOSIVES 1.5
1.6	EXPLOSIVES 1.6
2.1	FLAMMABLE GAS
2.2	NON-FLAMMABLE GAS
3	FLAMMABLE
Combustible Liquid	COMBUSTIBLE
4.1	FLAMMABLE SOLID
4.2	SPONTANEOUSLY COMBUSTIBLE
5.1	OXIDIZER
5.2	ORGANIC PEROXIDE
6.1 (PGI or II, other than PGI PIH)	POISON
6.1 (PGIII)	KEEP AWAY FROM FOOD
6.2	NONE
8	CORROSIVE
9	CLASS 9
ORM-D	NONE

For complete details, refer to one or more of the following:

- Code of Federal Regulations, Title 49, Transportation. Parts 100-199. [All modes]
- International Civil Aviation Organization (ICAO) Technical Instructions for Safe Transport of Dangerous Goods by Air [Air]
- International Maritime Organization (IMO) Dangerous Goods Code [Water]
- "Transportation of Dangerous Goods Regulations" of Transport Canada. [All Modes]

U.S. Department of Transportation
Research and Special Programs Administration

Copies of this Chart can be obtained by writing OHMIT/DHM-51, Washington, D.C. 20590

CHART 10 (REV. FEBRUARY 1994)

Figure 5.3—U.S. Department of Transportation's general placarding guidelines.

Table 5.1—A guide for separating imcompatible hazardous materials.

Segregation Table for Hazardous Materials

CLASS	Class or Division	Placard Weight	1.1 1.2	1.3	1.4	1.5	1.6	2.1	2.2	2.3 Gas Zone A	2.3 Gas Zone B	3	4.1	4.2	4.3	5.1	5.2	6.1 Liquids PG I, Zone A	7	8 Corrosive Liquids
EXPLOSIVES	1.1 1.2	Any quantity	✻	✻	✻	✻	✻	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖
EXPLOSIVES	1.3	Any quantity	✻	✻	✻	✻	✻	✖		✖	✖	✖	✖	✖	✖	✖	✖	✖		✖
EXPLOSIVES	1.4	1,001 lb	✻	✻	✻	✻	✻	O		O	O	O		O				O		O
VERY INSENSITIVE EXPLOSIVES	1.5	1,001 lb	✻	✻	✻	✻	✻	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖
VERY INSENSITIVE EXPLOSIVES	1.6	1,001 lb	✻	✻	✻	✻	✻													
FLAMMABLE GASES	2.1	1,001 lb	✖	✖	O	✖				✖	O							O	O	
NONFLAMMABLE, NONTOXIC GASES	2.2	1,001 lb	✖			✖														
POISONOUS GAS, ZONE A	2.3	Any quantity	✖	✖	O	✖		✖				✖	✖	✖	✖	✖	✖			✖
POISONOUS GAS, ZONE B	2.3	Any quantity	✖	✖	O	✖		O				O	O	O	O	O	O			O
FLAMMABLE LIQUIDS	3	1,001 lb	✖	✖	O	✖				✖	O					O		✖		
FLAMMABLE SOLIDS	4.1	1,001 lb	✖			✖				✖	O							✖		O
SPONTANEOUSLY COMBUSTIBLE MATERIALS	4.2	1,001 lb	✖	✖	O	✖				✖	O							✖		✖
DANGEROUS-WHEN-WET MATERIALS	4.3	Any quantity	✖	✖		✖				✖	O							✖		O
OXIDIZERS	5.1	1,001 lb	✖	✖		✖				✖	O							✖		O
ORGANIC PEROXIDES	5.2	1,001 lb	✖	✖		✖				✖	O							✖		O
POISONOUS LIQUIDS, PGI ZONE A	6.1	Any quantity	✖	✖	O	✖		O				✖	✖	✖	✖	✖	✖			✖
RADIOACTIVE MATERIALS	7	Any quantity (yellow III label)	✖			✖		O												
CORROSIVE LIQUIDS	8	1,001 lb	✖	✖	O	✖				✖	O		O	✖	O	O	O	✖		
NOTES			A			A			B	G	G	G				A		E		

49 CFR, SUBPART C, §177.848 INSTRUCTIONS FOR THE SEGREGATION OF HAZARDOUS MATERIALS

(1) The absence of any hazard class or division, or a blank space in the Table indicates that no restriction apply.
(2) The letter ✖ in the Table indicates that these materials may not be loaded, transported, or stored together in the same rail car or storage facility during the course of transportation.
(3) The letter **O** in the Table indicates that these materials may not be loaded, transported, or stored together in the same rail car or storage facility during the course of transportation unless separated in a manner that, in the event of leakage from packages under conditions normally incident to transportation, comingling of hazardous materials would not occur. Notwithstanding the methods of separation employed, Class 8 (corrosive) liquids may not be loaded above or adjacent to Class 4 (flammable) or Class 5 (oxidizing) materials; except that shippers may load carload shipment of such material together when it si know that the mixture of contents would not cause a fire or a dangerous evolution of heat or gas.
(4) The ✻ in the Table indicates that segregation amount different Class 1 (explosive) materials is governed by the compatibility table in paragraph (f) of this section.
(5) See instructions §177.848 (e)(5). The **A** in the NOTES row means that, notwithstanding the requirements of the letter ✖, ammonium nitrate (UN 1942) and ammonium nitrate fertilizer may be loaded or stored with Division 1.1 (Class A explosive) or Division 1.5 (blasting agents) materials.
(6) When the 172.101 Table or 172.402 of this subchapter requires a package to bear a subsidiary hazard label, segregation appropriate to the subsidiary hazard must be applied when that segregation is more restrictive than that required by the primary hazard. However, hazardous materials of the same class may be stowed together without regard to segregation required by any secondary hazard if the materials are not capable of reacting dangerously with each other and causing combustion or dangerous evolution of heat, evolution of flammable, poisonous, or asphyxiant gases, or formation of corrosive or unstable materials.

49 CFR, SUBPART C, §177.848 INSTRUCTIONS FOR THE SEGREGATION OF HAZARDOUS MATERIALS, ***continued***

(7) Class 1 (explosive) materials may not be loaded, transported, or stored together, except as provided in this section, and in accordance with the Table.
(8) The **B** in the NOTES row means: For domestic transportation of oxygen, compressed or oxygen, refrigerated liquid, the OXYGEN placard may be used in place of NONFLAMMABLE GAS placard (§172.504(f)(7)).
(9) The **E** in the NOTES row means: Packages with POISON, POISON INHALATION HAZARD, or HARMFUL KEEP AWAY FROM FOOD labels may not be transported with foodstuffs, feed, or any other edible material intended for humans or animals. For exceptions, see §177.841(e).
(10) The **G** in the NOTES row means: The old POISON GAS or TOXIC GAS placards may be used for highway and rail shipments until October 1, 2001.

Table 5.2—A guide for separating Class 1 incompatible explosive materials.

Compatibility Table for Class 1 (Explosive) Materials

COMPATIBILITY GROUP	A	B	C	D	E	F	G	H	J	K	L	N	S
A		✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖
B	✖		✖	4	✖	✖	✖	✖	✖	✖	✖	✖	4/5
C	✖	✖		2	2	✖	✖	✖	✖	✖	✖	3	4/5
D	✖	4	2		2	✖	✖	✖	✖	✖	✖	3	4/5
E	✖	✖	2	2		✖	✖	✖	✖	✖	✖	3	4/5
F	✖	✖	✖	✖	✖		✖	✖	✖	✖	✖	✖	4/5
G	✖	✖	✖	✖	✖	✖		✖	✖	✖	✖	✖	4/5
H	✖	✖	✖	✖	✖	✖	✖		✖	✖	✖	✖	4/5
J	✖	✖	✖	✖	✖	✖	✖	✖		✖	✖	✖	4/5
K	✖	✖	✖	✖	✖	✖	✖	✖	✖		✖	✖	4/5
L	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	1	✖	4/5
N	✖	✖	3	3	3	✖	✖	✖	✖	✖	✖	✖	4/5
S	✖	4/5	4/5	4/5	4/5	4/5	4/5	4/5	4/5	4/5	✖	4/5	

49 CFR, SUBPART C, §177.848 SEGREGATION OF HAZARDOUS MATERIALS

(1) A blank space in the Table indicates that no restrictions apply.
(2) The letter ✖ in the Table indicates that explosives of different compatibility groups may not be carried on the same rail car unless packed in separate freight containers (e.g., two or more freight containers mounted upon the same rail car).
(3) The numbers in the Table mean the following:
(i) The **1** means explosives from compatibility group L may only be carried on the same rail car with an identical explosive.
(ii) The **2** means any combination of explosives from compatibility group C, D, or E is assigned to compatibility group E.
(iii) The **3** means any combination of explosives from compatibility group C, D, or E with those in compatibility group N is assigned to compatibility group D.
(iv) The **4** means detonators and detonating primers, Division 1.4S (Class C explosives), may not be loaded in the same car with Division 1.1 and 1.2 (Class A explosive) materials.
(v) The **5** means Division 1.4S fireworks may not be loaded in the same car with Division 1.1, or 1.2 (Class A explosive) materials.
(h) Except as provided in paragraph (i) of this section, explosives of the same compatibility group but of different divisions may be transported together, provided that the whole shipment is transported as though its entire contents were of the lower numerical division (i.e., Division 1.1 being lower than Division 1.2). For example, a mixed shipment of Division 1.2 (Class A explosive) materials and Division 1.4 (Class C explosive) materials, compatibility group D, must be transported as Division 1.2 (Class A explosive) materials.
(I) When Division 1.5 (blasting agent) materials, compatibility group D, are transported in the same freight container as Division 1.2 (Class A explosive) materials, compatibility group D, the shipment must be transported as Division 1.1 (Class A explosive) materials, compatibility group D.

49 CFR 173.63—Shippers: General Requirements for Shipments and Packagings

§173.63 Packaging exceptions.

(a) Cord, detonating (UN 0065), having an explosive content not exceeding 6.5 g (0.23 ounces) per 30-centimeter length (one linear foot) may be offered for transportation domestically and transported as Cord, detonating (UN 0289), Division 1.4 Compatibility Group D (1.4D) explosives, if the gross weight of all packages containing Cord, detonating (UN 0065), does not exceed 45 kg (99 pounds) per:

(1) Transport vehicle, freight container, or cargo-only aircraft;
(2) Offshore down-hole tool pallet carried on an offshore supply vessel;
(3) Cargo compartment of a cargo vessel; or
(4) Passenger-carrying aircraft used to transport personnel to remote work sites, such as offshore drilling units.

(b) Cartridges, small arms, and cartridges power devices.

(1) Cartridges, small arms, and cartridges power devices (which are used to project fastening devices) which have been classed as a Division 1.4S explosive may be reclassed, offered for transportation, and transported as ORM-D material when packaged in accordance with paragraph (b)(2) of this section; such transportation is excepted from the requirements of Subparts E (Labeling) and F (Placarding) of part 172 of this subchapter. Cartridges, small arms, and cartridges power devices that may be shipped as ORM-D material is limited to:

(i) Ammunition for rifle, pistol or shotgun;
(ii) Ammunition with inert projectiles or blank ammunition;
(iii) Ammunition having no tear gas, incendiary, or detonating explosive projectiles;
(iv) Ammunition not exceeding 12.7 mm (50 caliber or 0.5 inch) for rifle or pistol, cartridges or 8 gauge for shotshells; and
(v) Cartridges, power devices which are used to project fastening devices.

(2) Packaging for cartridges, small arms, and cartridges power devices as ORM-D material must be as follows:

(i) Ammunition must be packed in inside boxes, or in partitions which fit snugly in the outside packaging, or in metal clips;
(ii) Primers must be protected from accidental initiation;
(iii) Inside boxes, partitions or metal clips must be packed in securely-closed strong outside packagings;
(iv) Maximum gross weight is limited to 30 kg (66 pounds) per package; and
(v) Cartridges, power devices which are used to project fastening devices and 22 caliber rim-fire cartridges may be packaged loose in strong outside packagings.

(c) through (e) [Reserved]

(f) Detonators containing no more than 1 g explosive (excluding ignition and delay charges) that are electric blasting caps with leg wires 4-feet long or longer, delay connectors in plastic sheaths, or blasting caps with empty plastic tubing 12 feet long or longer may be packed as follows in which case they are excepted from the packaging requirements of Sec. 173.62:

(1) No more than 50 detonators in one inner packaging;
(2) IME Standard 22 container or compartment is used as the outer packaging;

49 CFR 173.63—Shippers: General Requirements for Shipments and Packagings *(continued)*

(3) No more than 1000 detonators in one outer packaging; and
(4) No material may be loaded on top of the IME Standard 22 container and no material may be loaded against the outside door of the IME Standard 22 compartment.

(g) Detonators that are classed as 1.4B or 1.4S and contain no more than 1 g of explosive (excluding ignition and delay charges) may be packed as follows in which case they are excepted from the packaging requirements of Section 173.62: [[Page 433]]

(1) No more than 50 detonators in one inner packaging;
(2) IME Standard 22 container is used as the outer packaging;
(3) No more than 1000 detonators in one outer packaging; and
(4) Each inner packaging is marked *I.4B Detonators* or *1.4S Detonators*, as appropriate. [Amdt. 173-224, 55 FR 52617, Dec. 21, 1990, as amended at 56 FR 66268, Dec. 20, 1991; Amdt. 173-236, 58 FR 50536, Sept. 24, 1993; Amdt. 173-253, 61 FR 27175, May 30, 1996]

The following is taken from the IME Safety Library Publication No. 22, *Recommendations for the Safe Transportation of Detonators in the Same Vehicle With Certain Other Explosive Materials*.

Recommendations for the Safe Transportation of Detonators in a Vehicle With Certain Other Explosive Materials

I. General

Detonators and other Class 1 materials (Explosives A, B, C, and blasting agents) may be transported together on a vehicle using IME-22 containers or compartments only under the following conditions:

A. Products: Explosives that may be transported on the same vehicle are limited to:

1. Detonators
   a. Detonators, electric; 1.4 B and 1.4 S (Explosives C, or
   b. Detonators, electric; 1.1 B (Explosives A) that contain no more than one (1) gram of explosive (excluding ignition and delay charges) and are electric detonators (electric blasting caps) with leg wires four (4) feet or longer; or detonators (blasting caps) with empty plastic tubing twelve (12) feet or longer, or
   c. Detonators, nonelectric; detonator assemblies, nonelectric; 1.4 B or 1.4 S (Explosives C).

B. Class 1 materials (Explosives A, B, C, and blasting agents) excluding 1.1 A materials (initiating explosives), and forbidden explosives.

C. Packaging, Labeling and Marking

1. Packaging for Class 1 materials (Explosives A, B, C, and blasting agents) must be in accordance with the Hazardous Materials Regulations of the Department of Transportation.
2. Packaging for detonators described in paragraph A1 above are as follows:

Recommendations for the Safe Transportation of Detonators in a Vehicle With Certain Other Explosive Materials *(continued)*

a. Detonators, electric; 1.4 B and 1.4 S (Explosives C), and 1.1 B (Explosives A) that contain no more than one (1) gram of explosives and are transported in quantities of more than 1,000: The detonators ***must*** be packed in inner packagings (cartons or spools) that are packed in original outer packagings (cases) before loading in the IME-22 container or compartment.

b. Detonators, electric; 1.4. B and 1.4 S (Explosives C and 1.1 B (Explosives A) that contain no more than one (1) gram of explosives and are transported in quantities of 1,000 or less: The detonators must be packed in inner packagings (cartons or spools) before loading into the IME-22 container or compartment.*

c. Detonators, nonelectric; detonator assemblies, nonelectric, 1.4 B and 1. 4 S (Explosives C must be shipped in original outer packaging.

3. Inner packaging (cartons) is not required for electric detonators that are packed inside pasteboard tubes or wound on spools with the detonator placed inside the spool so as to restrict freedom of movement of the detonator and protect them from impact forces.
4. No material is to be loaded ***on top*** of a portable IME-22 container which contains Class 1 materials (explosive) nor is any material to be loaded against the outside of the door of an IME-22 compartment. Portable IME-22 containers shall be secured to prevent movement during transport.
5. When Class 1 (explosive) materials are loaded into a portable IME-22 container, the warning *Contains Explosives, Handle Carefully* must be displayed on the container's lid in letters at least 1/2-inch high.
6. Labeling and marking of the IME-22 container or compartment containing detonators is not required when the compartment is an integral part of the vehicle body or the container is permanently attached to the motor vehicle. This applies even when the detonators are in inner packaging only, as authorized in paragraphs B2a and B2b above, and the vehicle contains any quantity of Class 1 materials (Explosives A, B, C, and blasting agents) and is placarded accordingly.

C. IME-22 Containers and Compartments

1. A portable IME-22 container placed within and readily removable from the cargo-carrying space of the vehicle.
2. An IME-22 container securely attached:
   a. Above the cab of the vehicle (Figure 5.4).
   b. To the vehicle under the cargo space (Figure 5.5).
3. A built-in compartment in the cargo space of the vehicle (Figure 5.6).

D. Placards

When using the United Nations (UN) placarding system, mixed shipments of Class 1 materials (Explosives A, B, C, and blasting agents) are to be placarded with the lowest division number of the cargo load.

*No specification or recommended outer packagings (original shipping cases) are required. Inner packagings (cartons or spools) of 1.4 B and 1.4 S detonators (Explosive C) must be so classified and marked or they must be described as detonators 1.1 B (Explosive A) on the shipping papers.

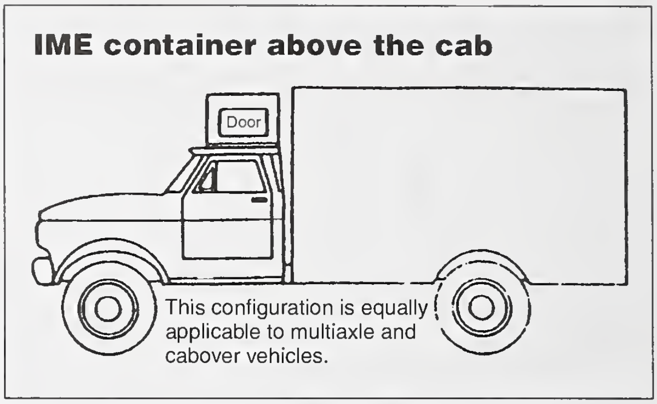


Figure 5.4—IME container is stored above the cab.

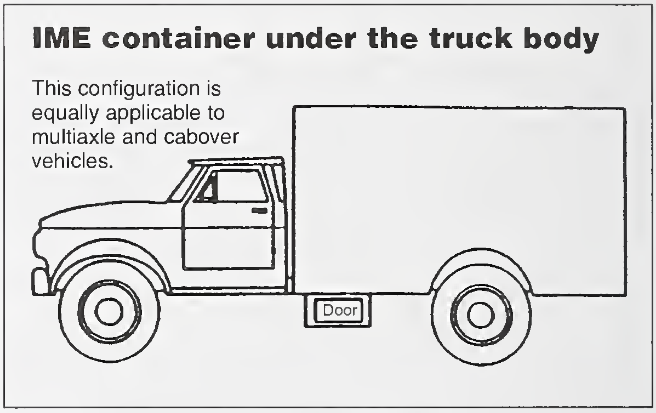


Figure 5.5—IME container is under the truck body.

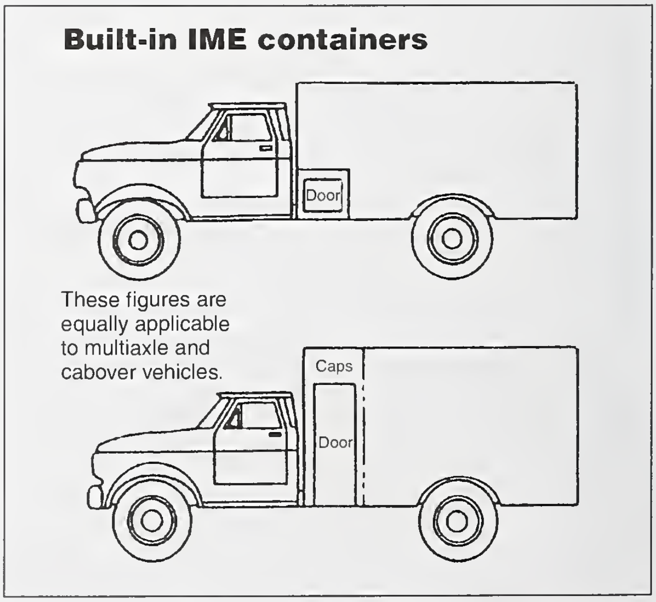


Figure 5.6—Examples of other IME containers *(continued on next page)*.

Recommendations for the Safe Transportation of Detonators in a Vehicle With Certain Other Explosive Materials *(continued)*

The Compatibility Group assigned to a mixed shipment will be that of the cargo load (excluding the IME-22 container).

The contents of the IME-22 container are treated as an authorized compatibility combination in accordance with 49 CFR, Part §177.848.

E. Use of the IME-22 Container or Compartment In the combined transportation of detonators and Class 1 materials (Explosives A, B, C, and blasting agents), either the detonators or the Class 1 materials (Explosives A, B, C, and blasting agents) may be transported in the IME-22 container or compartment.

II. Construction

The IME-22 container or compartment construction detail shown in Figure 5.7 provides for the interchange of 1/2-inch sheetrock with 1/4-inch asbestos board when either is preferred over the other. This interchange is not authorized in an IME-22 container or compartment constructed in the manner, and with the materials specified (Figure 5.8). A means to release the pressure developed by accidental detonation of the contents without allowing debris to escape has been provided through the venting procedure outlined in paragraph H below. No other changes in the construction specifications or materials are authorized.

A. **The IME-22 container** or compartment must provide for total enclosure of the contents.

B. **The top, lid or door, sides and bottom surfaces** of each IME-22 container or compartment must be a laminate construction of A/C grade or better exterior plywood, sheetrock, and low-carbon steel. In order of arrangement, from inside to outside, the laminate must consist of the following with *minimum* thickness of each lamination as indicated: Half-inch plywood, 1/2-inch sheetrock, 1/8-inch low-carbon steel, a 1/4-inch lamination of A/C plywood is required on the exterior portion of a container or compartment that may contact other explosives carried on the same vehicle. See Figures 5.7 and 5.8 for details of laminate construction.)

C. **The laminated materials** must be securely bound together by waterproof adhesive or other equally effective means.

D. **The steel at the joints of lamination** must be secured by continuous fillet welds.

E. **All interior surfaces** of the IME-22 container or compartment must be constructed so as to prevent contact of the contents with any sparking metal. The exterior portion of a container or compartment that may contact other explosives carried on the vehicle must be nonsparking.

F. **There must be direct access** to the IME-22 container or into an IME-22 compartment from outside the vehicle.

Built-in IME containers

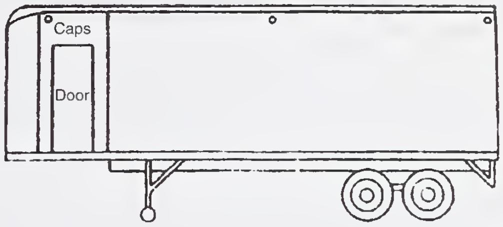


Figure 5.6—*Continued.*

IME container construction details

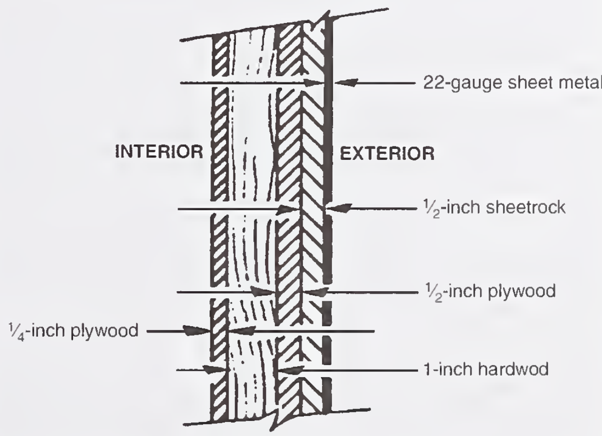


Figure 5.7—Recommended construction of an IME container using 22-gauge sheet metal.

IME container construction details

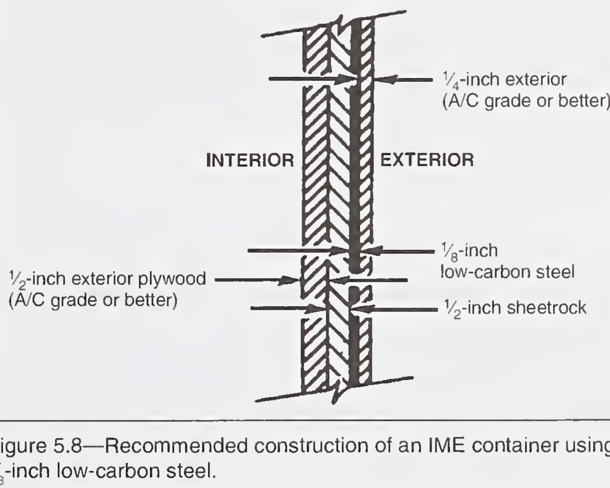


Figure 5.8—Recommended construction of an IME container using 1/8-inch low-carbon steel.

Recommendations for the Safe Transportation of Detonators in a Vehicle With Certain Other Explosive Materials *(continued)*

G. **Each IME-22 container** or compartment must have a snug-fitting lid or door and be equipped with a means to provide for locking or sealing if required.

H. **Without permitting direct access** to contents under normal conditions, the locking or hinging mechanisms must permit at least one edge of the lid or door to rise or move outward at least ½-inch when subjected to internal pressure.

I. **The exterior of the IME-22 container** or compartment must be weather resistant. Weather resistance may be provided by A/C marine, or better grades of plywood, or through other methods such as fiberglass, epoxy coatings, weather-resistant paints or comparable exterior coatings or coverings.

J. **As an alternative to the construction requirements** shown in paragraph B above, an IME-22 container may be constructed as follows:
1. The top, lid or door, sides and bottom surfaces of each IME-22 container or compartment must be a laminate construction of A/C grade or better exterior plywood, solid hardwood, asbestos board or sheetrock and sheet metal. In order of arrangement, from inside to outside, the laminate must consist of the following with the minimum thickness of each lamination as indicated: ¼-inch plywood, 1-inch solid hardwood, ½-inch plywood, ½-inch sheetrock or ¼-inch asbestos board, and 22-gauge sheet metal constructed inside to outside in that order. See Figure 5.7 for details of laminate construction.
2. The hardwood must be fastened together with wood screws, the ½-inch plywood must be fastened to the hardwood with wood screws, the inner ¼-inch plywood must be fastened to the hardwood with adhesive and the 22-gauge sheet metal must be attached to the exterior of the IME-22 container with screws.

III. Identification

The interior surface of lid or door of an IME-22 container or compartment must be marked in letters and numbers at least ½-inch high as follows: *BARRIER LAMINATE, MEETS SLP #22.*

5.3 Transporting Explosives With Packstock

Packstock may carry explosives in remote areas with these restrictions:

* Animals must be in good physical condition, well shod, well trained for pack use, gentle, free of bad habits, and have been worked recently.

* Handlers shall be experienced in handling packstock and be either certified or accompanied by a person certified for transporting and storing explosives.

* Packsaddles, ropes, and other equipment must be inspected and in good condition.

* Detonators and explosives must be packed on separate animals just before departure.

* Detonators must be packed in original containers with voids filled and well-wrapped and padded with nonmetallic articles, such as bedrolls and tents.

* Explosives must be packed in original cases and covered with a flameproof and moistureproof tarpaulin. Experienced packers must tie up bundles and rope them to packsaddles.

* Travel one-half hour after sunrise to one-half hour before sunset.

* Use of drugs or alcohol is prohibited.

* In lightning or storms, unload packstock if time permits and move the string a safe distance away. If there is no time to unload, securely tether the pack animals carrying explosives and move the remaining string a safe distance away.

* Consult Tables 3.2 through 3.6 for the minimum distance a radio can be operated from stock carrying EBC's.

* No placards are required for a packstring carrying explosives.

5.4 Transporting Explosives With Trail Vehicles and ATV's

Motorized cargo carriers and ATV's may be used on limited jobs to move explosives in remote areas. Observe these restrictions:

* Never transport impact-sensitive explosives with a two-wheel vehicle.

✱ Thoroughly inspect all carriers and ATV's and correct deficiencies before use. Carriers and ATV's (including engines) must be clean and in good mechanical condition.

✱ Equip all carriers and ATV's with approved spark arresters and one pressure-type dry-powder or carbon-dioxide fire extinguisher, rated 2-BC or better.

✱ Do not exceed the manufacturer's recommended load rating. In no case shall the weight of the explosives exceed 200 pounds.

✱ Never transport detonators in the same cargo carrier or ATV with other explosives.

✱ Use operators that are certified and experienced in operating cargo carriers or ATV's. Operators must be certified to transport and store explosives or be accompanied by someone who is.

✱ When loads include other equipment, tools, and supplies, limit explosives to no more than 50 pounds. When transporting such mixed cargo, pack the explosives in a metal box with a minimum ½-inch sponge-rubber lining, hinged lid, and hasp. Fill all voids in the box. Paint the box red and stencil the word *Explosives* on top in 2-inch-high white letters. Secure the box to the bottom of the cargo deck or cargo rack away from the engine.

✱ Travel only between one-half hour after sunrise to one-half hour before sunset.

✱ Use of drugs or alcohol is prohibited while transporting explosives.

✱ Park the cargo carrier or ATV during lightning or storms and move all personnel a safe distance away.

✱ Consult Tables 3.2 through 3.6 for the minimum distance a radio can be operated from a cargo carrier with EBC's.

✱ Post explosives placards scaled to the space available on the carrier or ATV.

5.5 Transporting Explosives by Vessels

Regulations—Shipments of explosives and other dangerous articles aboard vessels (including lighters and barges) by commercial service shall conform to the DOT's Title 49 Part 176, Subpart E, *Special Requirements for Transport Vehicles Loaded With Hazardous Materials and Transported Onboard Ferry Vessels.*

On any vessel:

✱ Explosives must be placed upon a wooden platform.

✱ Carry all blasting caps and detonators on deck as far forward as possible, in their original cartons, in a watertight, wood-lined-steel portable cap magazine.

✱ If small vessels are involved, carry the explosives on one and the caps on the other. Or if transporting the explosives to a destination where they will be unloaded, such as a barge, make one trip with the explosives and a second trip carrying the caps.

✱ Situate explosives away from loading booms or hoists, where they will not be exposed to falling objects. Keep them isolated from potential sources of static electricity, heat, and radio-frequency energy.

✱ A vessel carrying explosives must fly the *Bravo* flag at the bow. However, since this is not likely to be understood by many boaters, *Explosives* signs should also be used in congested waters.

49 CFR Subpart E—Special Requirements for Transport Vehicles Loaded with Hazardous Materials and Transported Onboard Ferry Vessels

§176.88 Application. The requirements in this subpart are applicable to transport vehicles containing hazardous materials being transported on board ferry vessels and are in addition to any prescribed elsewhere in this subchapter. Vessels in a service similar to a ferry service, but not over a designated ferry route, may be treated as a ferry vessel for the purpose of this subpart if approved in writing by the District Commander. [Amdt. 176–1, 41 FR 16110, Apr. 15, 1976, as amended by Amdt. 176–1A, 41 FR 40690, Sept. 20, 1976]

The requirements in this subpart are applicable to transport vehicles containing hazardous materials being transported onboard ferry vessels and are in addition to any prescribed elsewhere in this subchapter. Vessels in a service similar to a ferry service, but not over a designated ferry route, may be treated as a ferry vessel for the purpose of this subpart if approved in writing by the Commander.

(a) A transport vehicle containing hazardous materials may be transported on board a ferry vessel, subject to the following conditions:
   (1) The operator or person in charge of the vehicle shall deliver to the vessel's representative a copy of the shipping papers and certificate required by §176.24 and §176.27;
   (2) The vehicle shall be placed at the location indicated by the vessel's representative;

49 CFR Subpart E—Special Requirements for Transport Vehicles Loaded with Hazardous Materials and Transported Onboard Ferry Vessels
(continued)

(3) The parking brakes of the vehicle shall be set securely to prevent movement;
(4) The motor of a highway vehicle shall be shut off and not restarted until the vessel has completed its voyage and docked;
(5) All vehicle lights shall be cut off and not relighted until the vessel has completed its voyage and docked;
(6) The operator of a highway vehicle shall remain with the vehicle;
(7) No repairs or adjustments must be made to the vehicle while it is on the vessel;
(8) No hazardous materials are to be released from the vehicle; and
(9) Any instructions given by the vessel's representative during the voyage, and during "roll on" and "roll off" operations must be observed.

(b) Smoking by any person in or around a vehicle is prohibited.

5.6 Transporting Explosives by Aircraft

Aircraft can transport explosive materials when the following conditions are met:

* Prepare and package all explosives under the supervision of a Certified Blaster. Transport in undamaged original shipping containers. A *Shipper's Declaration For Dangerous Goods* must be completed (Figure 5.9, following page).

* Do not transport high explosives in the same container as detonators and keep separate from detonating materials. Carry detonating materials and explosives on different flights whenever possible and practical.

* For separation purposes, EBW's may be carried inside aircraft while explosive materials are transported by internal or external load, provided the detonators are contained in the original manufacturer package or packaged in an IME container. EBC's, Nonel, and crimp caps must be packaged in an IME container and kept as far from the explosives as practical.

* Do not transport explosives that will react with oil, flames, acids, storage batteries, oxidizing, or corrosive compounds on the same flight with the reacting materials unless separation of the materials can be achieved to prevent possibility of contact between such materials.

* Explosives and detonators transported in the aircraft or on external cargo racks must be stowed separately, secured by tiedown straps, and be accessible for jettisoning whenever possible and practical.

* No passengers other than those absolutely necessary for the completion of the mission involving the transport or use of explosives will be allowed on a flight transporting explosive materials.

* All explosives, ammunition, and detonating materials must be transported under the control or direction of a certified Blaster.

* Flights transporting high explosives or detonating materials will not be conducted over densely populated areas or in congested airways. During the approach and landing phase, the aircraft pilot shall request appropriate vectors when under radar control to avoid heavily populated areas. Wherever Class A or B (1.1, 1.2, 1.3) explosives are transported and a danger exists to people on the ground, advance permission from the owner or operator of any manned airport used must be obtained (Figure 5.10, following pages).

* No aerial dispensing of an explosive device will be conducted unless the dispensing method and/or dispensing device has been approved and accepted by the Forest Service.

* The pilot shall ensure that no smoking, or the use of any open flame or spark-producing device, will be allowed while transporting explosives, ammunition, or initiating devices.

* Label all packages containing explosives on the outside of the package with the appropriate hazardous materials warning label.

* In fire operations, only those explosives approved for use as a fireline explosive will be loaded on aircraft. In special operations, only the less sensitive explosives will be loaded on aircraft (for example, watergels, emulsions, two-component explosives, and det cord).

* When explosives and blasting caps are carried for avalanche-control flights, the explosives must be handled—and at all times—be under the control of the Blaster. The Blaster must be licensed under the appropriate authority identified in writing to the FAA Civil Aviation Security Office responsible for the aircraft operator's overall aviation security program or the FAA Civil Aviation Security Office in the region where the aircraft operator is located.

SHIPPER'S DECLARATION FOR DANGEROUS GOODS

Shipper	Air Waybill No. Page of Pages Shipper's Reference Number *(optional)*
Consignee	
Two completed and signed copies of this Declaration must be handed to the operator	**WARNING**
TRANSPORT DETAILS This shipment is within the limitations prescribed for: *(delete non-applicable)* PASSENGER AND CARGO AIRCRAFT | CARGO AIRCRAFT ONLY Airport of Departure	**Failure to comply in all respects with the applicable Dangerous Goods Regulations may be in breach of the applicable law, subject to legal penalties. This Declaration must not, in any circumstances, be completed and/or signed by a consolidator, a forwarder or an IATA cargo agent.**
Airport of Destination:	Shipment type: *(delete non-applicable)* NON-RADIOACTIVE | RADIOACTIVE

NATURE AND QUANTITY OF DANGEROUS GOODS

Dangerous Goods Identification						
Proper Shipping Name	Class or Divi-sion	UN or ID No.	Subsi-diary Risk	Quantity and type of packing	Packing Inst.	Authorization

Additional Handling Information

I hereby declare that the contents of this consignment are fully and accurately described above by proper shipping name and are classified, packed, marked and labelled, and are in all respects in the proper condition for transport by air according to the applicable International and National Government Regulations.	Name/Title of Signatory Place and Date Signature *(see warning above)*

STYLE F83 LABELMASTER, CHICAGO, IL 60646

Figure 5.9—A *Shipper's Declaration for Dangerous Goods* must be completed to transport explosives by aircraft.

Operating Authority for Aircraft Carrying Explosives

Approval to operate aircraft carrying explosives must be obtained in advance from airport authorities under provisions of 49 CFR 1/5.320.

Authority to operate at ________________________ Airport has been obtained from

________________________ whose phone number is (_____) ________________.

The following restrictions apply to operation at this airport:

Approach and departure routes ________________________

____

____

Landing and takeoff ________________________

____

____

Parking/refueling ________________________

____

____

Loading and/or unloading ________________________

____

____

By Forest Service or BLM Officer:

Signed ________________ Title ________________

Date ________________ Time ________________

I hereby certify that the contents of this shipment are fully and accurately described above by proper shipping name and are classified, packed, marked, and labeled, and in proper condition for carriage by air according to aplicable DOT regulations. This shipment is within the limitations prescribed for cargo-only aircraft.

Figure 5.10—Obtain permission and instructions from the airport authority for aircraft carrying explosives to use the facility.

* Any aircraft that is carrying explosives and makes a forced landing for minor repairs will not unload its cargo, but will be repaired at a safe distance in accordance with the quantity-distance requirements in Chapter 4. Any aircraft forced down for major repairs will be stored at a safe distance in accordance with the applicable quantity-distance tables.

* Any aircraft carrying explosives making a landing to refuel will not unload its cargo, but will refuel in accordance with the quantity-distance requirements (Chapter 4).

* Before requesting taxiing, takeoff, landing, or parking instructions, the pilot of an aircraft loaded with explosives will notify the control tower of the cargo and request special consideration and priority.

* The quantity-distance tables will be observed in parking aircraft loaded with ammunition and explosives and such aircraft will be adequately guarded.

* Explosive placards will be displayed when an aircraft loaded with explosives is parked and during all loading and unloading operations. Appropriate fire symbols shall be placed alongside the placards at all airfields.

Chapter 6—Blasting Procedures

6.1 Drilling

Make boreholes large enough to insert the explosives cartridges freely.

Do not start drilling until all remaining butts or old holes are examined for unexploded charges. If any are found, refire them before drilling work proceeds.

Never deepen drill holes that have contained explosives or blasting agents.

Never deepen drill holes unless the Blaster has ***direct knowledge*** that the hole has never been loaded.

Check holes before loading to determine conditions and depth. Do not drill within 50 feet of a hole that is loaded with explosives.

6.2 Signing

The Blaster-in-Charge is responsible for posting flaggers or guards and warning signs, notifying all persons in the blast area, and giving all necessary audible warning signals.

All signing must conform to the *Manual of Uniform Traffic Control Devices* (MUTCD) for streets and highways whenever blasting operations are conducted. The *Blasting Zone 1,000 Feet* sign (Figure 6.1) is to be placed 1,000 feet in front of any point or work site where explosives are being used. The *Turn Off 2-Way Radio* and *End Blasting Zone* signs (Figure 6.2) must also be used with the *Blasting Zone 1,000 Feet* sign. Provisions shall be made for covering or removing the sign sequence when no explosives are in the area or when the area is otherwise secured.

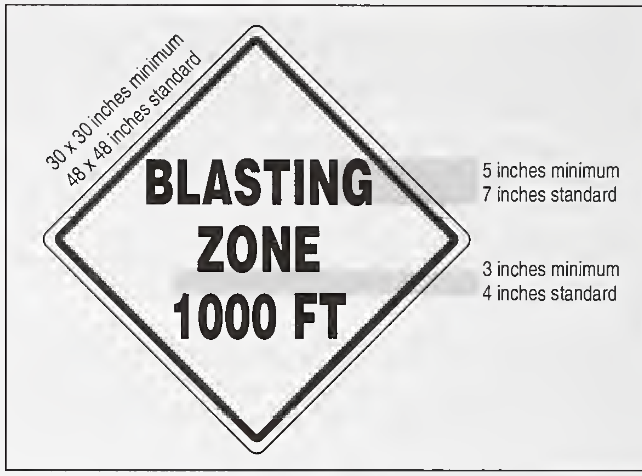


Figure 6.1—Post this sign at sites where explosives are being used.

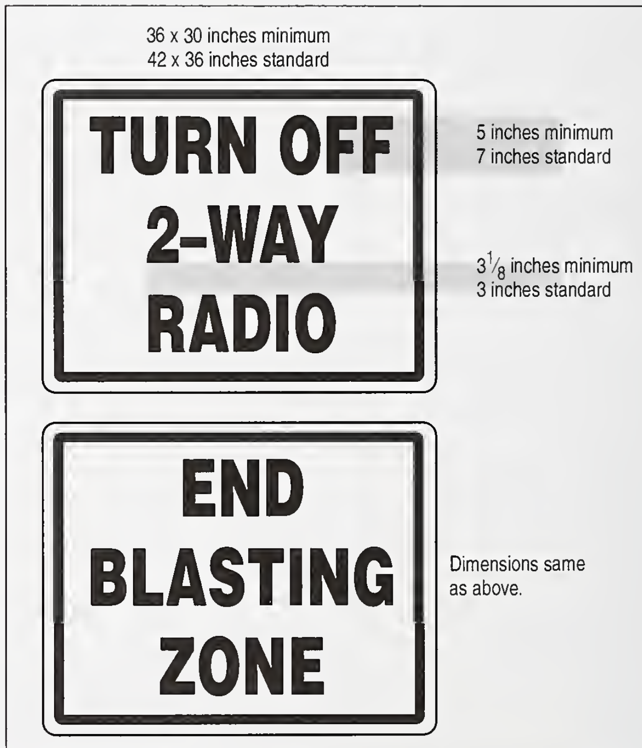


Figure 6.2—These signs are always used with the *Blasting Zone 1,000 Feet* sign.

6.3 Guarding

The Blaster-in-Charge is responsible for assigning guards to ensure the safety of all persons in the vicinity of the blast site. The numbers and placement of these guards will be determined by the Blaster-in-Charge, and may vary from site to site.

When the first verbal blast warning is given by the Blaster-in-Charge, guards will ensure that all pedestrian and vehicle traffic is stopped a minimum of 700 airline feet from the blast site, and detained until the *all clear* is given. Guards will maintain verbal or radio contact with the Blaster-in-Charge.

Before the blast, guards will visually survey the area surrounding their position, searching for anyone who might wander into the blast zone, and give immediate notice to the Blaster-in-Charge of any such occurrence.

The Blaster-in-Charge and any blasting assistants will be a minimum of 500 feet (152 m) from the blast site. Increase this distance depending on the size of the shot or anticipated flyrock.

6.4 Communications

Good communications between all members of a blasting crew are essential. Radio contact between guards and the Blaster-in-Charge is needed to ensure blast site security in most situations. On some projects horns or whistles may be used to maintain site security. If EBC's are being used at a blast site, be careful when using a radio transmitter in the vicinity (Tables 3.2 to 3.6). Use only low-wattage, handheld UHF portables within 500 feet (152 m) of the blast site. If the portable radio has a high-low switch, use the low position, which transmits at about 1 watt.

Before transmitting, shunt all detonator wires and move away from the shot. Road guards that are 500 feet (152 m) or farther away may use UHF mobile radios, provided the output wattage is not greater than 20 watts.

6.5 Loading

Before beginning loading, establish safe and efficient procedures. Load only those holes to be fired in the next round of blasting.

Before loading, check the hole to confirm the desired depth. A nonsparking tamping pole marked with electrician's tape at 1-foot intervals, works well to measure borehole depth. Nonsparking metal connectors may be used for jointed poles.

If only one cartridge is needed, gently lower it into the hole while suspending it by the leg wires, a shock tube, or det cord. ***Never tamp*** primed cartridges. Carefully add stemming material to the hole. After enough stemming material has been added to cushion the primer, the remaining stemming material may be tamped. Be careful not to damage the wires, cord, or shock tube. Avoid violent tamping.

When more than one cartridge is used, slit the side of the cartridges—***do not*** slit the primer. Carefully place them on top of the primer as they are lowered into the hole. Do not drop cartridges into the hole on top of the primer. Use a tamping pole to apply gentle pressure against the cartridges that have slits. This compresses the explosive and presses it against the sides of the borehole, creating good coupling. Progressively stem and tamp the hole until the hole is filled.

Stemming is usually an inert material, such as gravel, sand, or drill cuttings. Small rock chips the size of pea gravel make ideal stemming because they compress tightly, containing the gases in the borehole. Sand or drill cuttings will often shoot out of the hole at detonation. In solid rock, the depth of stemming should be equal to the burden (the distance from the hole to the face). In rock containing cracks and crevices, stemming is decreased and may be only seven-tenths of the burden (Chapter 9).

✱ Never leave loaded holes unattended or unprotected. Blasters must schedule work to ensure that loaded holes or charges will be shot before Blasters leave the site.

✱ Never leave explosives or blasting agents unattended at the blast site.

✱ Do not operate equipment within 50 feet of loaded holes.

✱ Never load a hole that is hot because of geothermal activity or drilling.

✱ After loading, immediately remove all excess explosives and detonators from the blast area.

✱ If an electrical storm approaches and holes are already loaded, keep the danger area clear and post guards in the same manner as when shots are fired. If the holes have not been connected to the lead wire, do not shunt the series; leave it open.

✱ If more than one Blaster has been loading holes in the same area, the Blaster-in-Charge will check the wiring or shock tube to ensure that all charges are properly connected in the circuit.

6.6 Connecting Detonators

Electric Detonators—Wire all caps in series. Do not wire more caps in a series than the rated capacity of the blasting machine.

For multiple shots, use standard 14-gauge or larger insulated solid-copper wire with no bare joints. Tape splices and support them so they are off the ground. Have Regional Blaster Examiner approval before using 20-gauge firing line on any detonation systems other than exploding bridgewire systems.

Provide enough lead wire to permit the Blaster and crew to be at least 500 airline feet away from the nearest explosive charge.

Prevent lead wires and detonator wires from being thrown into any part of a telephone line, transmission line, or other electrical installation.

After the lead wires have been wired into the circuit and all connections are tight, check the circuit with an approved galvanometer or an approved Blaster's ohmmeter to see if the circuit is closed. This check must be made ***before*** attaching lead wires to the blasting machine.

Use only approved blasting machines and initiation devices. Capacitor-discharge blasting machines are rated as follows:

* 32 ohms for 10-cap machines (caps wired in a series)
* 144 ohms for 30-cap machines
* 208 ohms for 50-cap machines.

Nonelectric Detonators—Connect all caps into shock cord lines following the manufacturer's recommendations. Watch carefully for the progression of the shot and how it is initiated. Use only approved initiation devices such as the shotshell primer or spark initiators.

The Blaster-in-Charge will make the final connections to the blasting machine or initiation device. The Blaster-in-Charge will be responsible for this machine or device until the project is completed.

Where practical, keep the blasting machine or initiation device in a moistureproof secure location. Do not remove the machine or device until just before it is to be used.

6.7 Firing

6.7.1 General Safety

The Blaster-in-Charge must ensure that everyone is in a safe location. Each location should provide protection from flyrock, concussion, and toxic fumes. Considerations must be given to the size and number of charges and the type of material being blasted. The Blaster-in-Charge is the last person to leave the blast area.

No one is allowed to be in front of a shot; everyone must be off to one side and at least 500 airline feet from the nearest explosive charge. Increase this distance according to the size of the shot and the potential for flyrock. Stop pedestrian and vehicle traffic at least 700 airline feet from the blasting area when the first warning signal is given. Detain vehicles and pedestrians until the area is cleared by the Blaster-in-Charge.

All personnel should face the blast with their backs to the sun, if possible, so they have the best chance to watch for and avoid flying debris. Shelters or other suitable protection from flyrock should be readily available. Instruct those present about when and how they should protect themselves. Everyone shall wear a hardhat.

Establish communications with all guards before beginning to hook up the shot. If low-wattage radios are being used at a site where electric blasting caps are used, observe the minimum distances shown in Tables 3.2 through 3.6.

6.7.2 Firing Procedures

The Blaster-in-Charge may shout or use a bullhorn to warn anyone who may be in the vicinity of the blast area. The Blaster-in-Charge will follow accepted local procedure when determining whether to use the warning signal, *Fire in the hole one, Fire in the hole two,* or *Blasting one, Blasting two.*

The timing and spacing of warnings varies according to the blasting system being used. The Blaster-in-Charge makes determinations based on the guidelines that follow. In all cases, the warning will be given three times before each shot, with enough time to allow all persons to reach a point of safety.

1—*Fire in the hole one* or *Blasting one* will be given when all holes are loaded and connected to each other, but before hookup to the lead line, trunkline, or shock tube.

2—*Fire in the hole two* or *Blasting two* will be given when the Blaster reaches the location where the blasting machine or initiator will be connected to the wire or shock tube. The warning signal will be given before hookup. For remote-control units, this location may be 50 to 100 feet from the shot, or where the remote control unit is located.

3—*Fire in the hole* or *Blasting now* is given just before detonating the shot. The shot will not be fired until the *All clear to proceed* signal is given by the guards to the Blaster-in-Charge, indicating that no one has entered the blast area. Blasters using Osprey remote-control systems may want to enter the first five digits of the code and then recheck with guards before the final verbal warning sign.

Immediately after the blast, the Blaster-in-Charge secures the blasting machine or initiator. Shunt the electric wires and switch remote-control units off. The Blaster-in-Charge cautiously returns to the shot after toxic fumes have dissipated. The Blaster-in-Charge checks for unexploded charges, unstable slopes or conditions, limbs that are hanging loosely in trees, or any other hazard.

Guards should not allow anyone into the blast area until the Blaster-in-Charge has given an *All clear* signal.

6.7.3 Postblast Procedures

After firing the shot, the Blaster-in-Charge:

1—Allows enough time for smoke and toxic fumes to dissipate before returning to blasting area.

2—Traces wires or shock tube through the broken rock and conducts a search for any unexploded cartridges and misfires before work is resumed or the crew is allowed to return to the area.

3—Gives the *All clear* signal before personnel return to the blast area or traffic flow is resumed.

4—In the event of a misfire, the Blaster-in-Charge takes action to safeguard all personnel.

6.8 Misfires

Most misfires are due to some problem with the initiation system, such as failure to make a connection, a broken lead wire, poor battery condition, or simply a failure to understand the initiation system. Other causes are inadequate priming, (some explosives are not sensitive to certain detonators), explosives malfunctioning due to improper storage, and cutoff because of improper delay sequencing. Misfires may be caused by explosives that have expired (usually indicated by shelf life or date code). Some explosives become less sensitive with time and temperature.

If none of the holes detonate, detecting a misfire is not difficult. However, if just a few holes or portions of a single hole fail to detonate, detecting the misfire can be very difficult and dangerous. In the event of a misfire, notify the guards and observe the following procedures:

1—If a misfire is thought to be associated with the initiation system, wait at least 30 minutes.

–For electric shots, disconnect the lead wires, and check them with the galvanometer or ohmmeter to determine if the load exceeded the rated capacity of the blasting machine. Check for a broken or grounded circuit. If the problem is resolved, connect the wires and detonate.

–For nonelectric shots, misfires are usually a result of incorrect shock-tube connections. This can be a failed splice, or improper placement of low-strength surface detonators. Any cuts in the tubing from rock or shrapnel can also cause a nonelectric misfire, as can moisture entering the shock tube. Always cap the loose end of the shock tube (bulk spool) when moisture is present or before storing the spool in a magazine.

–Detonating-cord misfires can occur from poor splicing or knot tying, or from failure to maintain 90-degree angles at all intersections. Other causes include loops contacting trunkline or downline, "tails" extending from knots or connections, improper detonator contact, and moisture entering the det cord's core because of poor storage or handling.

–For misfires involving the Osprey remote system, try transmitting the code sequence a second time with the radio switched to high power. Check all batteries in the

transmitter and receiver. If the shot fails to fire, the Blaster-in-Charge must wait until the receiver automatically shuts down (20 minutes) before returning to the receiver. No waiting time is required if EBW's are used.

2—The Blaster-in-Charge approaches the blast area alone and observes from a safe distance to determine if all the charges have detonated. If any sign of a burning charge is detected, evacuate the area. Post the area and guard it for 12 hours before returning.

3—If no sign of a burning charge is detected, check for irregularities in the muck pile. If detonating cord, leg wires, or tubes are protruding from a hole, inspect them closely and check the circuit with a galvanometer. If none of these components are damaged, they can be connected and fired again.

4—If a misfire is in solid material that has been stemmed and tamped or otherwise confined, the stemming must be removed to expose the powder column before priming and shooting. Remove stemming from a borehole by using a plastic pipe or hose to direct a gentle stream of water or compressed air. You can also use your hands or a piece of wood to remove stemming. Do not use shovels or other metal tools. Do not pull on wires or shock tubes. Make a fresh primer, place the primer in direct contact with the misfired explosive and fire again. ***Never*** attempt to drill another hole near a misfired charge.

Chapter 7—Geological Effects on Blasting

7.1 General

Geology helps determine how well a blast will break and move rock. Heavy, dense rock requires more energy to break than does light, loose rock. Less energy is required to move seamy rock layers and even less energy is needed to move soil. The more information that is available on a geologic formation, the easier it is for the Blaster to establish an appropriate blast design. On large, complex projects, Blasters should consult with a geologist or a geotechnical engineer.

7.1.1 Basic Geology for Blasters

Forest Service geologists routinely use the *Unified Rock Classification System* (URCS) when analyzing a rock mass. Doug Williamson, a retired geologist from the Willamette National Forest, developed the URCS. The URCS allows rapid preliminary assessments of rock conditions by simple field tests that establish the natural strength characteristics of rocks. Engineering geologists and geotechnical engineers using this classification system have found that it provides a practical understanding of an entire rock mass. Additional investigation and testing may be required, depending on the funds available and risks that can be accepted. This section is intended to provide the Blaster with some practical information that can be applied to rock blasting projects.

7.2 Determining Sonic Velocity and Specific Gravity

Two important parameters that must be determined for any rock or soil mass are the sonic velocity (VSO) expressed in feet per second and the specific gravity (SG). Both values are used to develop an appropriate blast design.

Determining Sonic Velocity—Select a piece of rock free of weathering and hit it with the rounded part of a 1-pound ball peen hammer. The impact may have four distinct reactions. The reaction does not depend on the force of the blow (within the limitations of the hammer and the investigator's strength). The reactions are termed *craters, dents, pits,* and *rebounds* (Figure 7.1).

Crater-Quality rock material reacts under the point of impact with shearing and upthrusting of adjacent mineral grains. This category of rock has an estimated VSO of 8,000 to 10,000 fps. The rock material can usually be recovered during rock core-drilling operations, has high absorption, and will respond to freeze/thaw stresses by cracking and checking. This type of rock has very low energy transfer when explosives are used. It can often be excavated and ripped without blasting.

Dent-Quality rock material will have a "dent" or depression under the point of impact. The dent indicates the presence of pore space between the mineral grains. This type of rock has an estimated VSO of 11,000 to 13,000 fps, roughly equivalent to the strength of concrete, although it responds to blasting differently. Dent-quality material has low energy transfer in response to blasting and often produces sand and boulders.

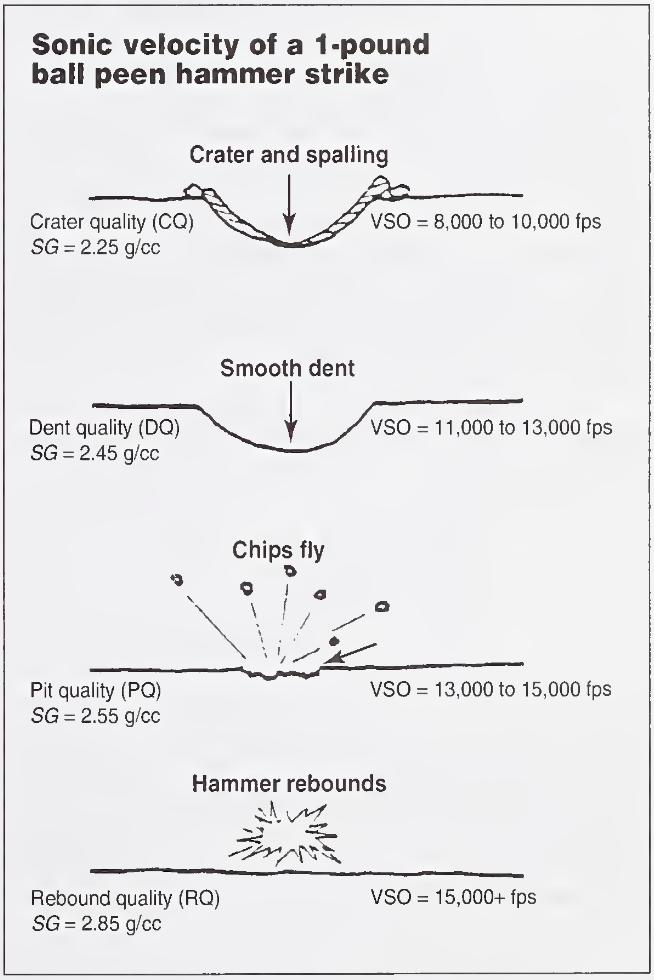


Figure 7.1—Some velocities as indicated by the strike of a 1-pound ball peen hammer.

Pit-Quality rock material produces explosive mineral grains (chips fly) under the point of impact, resulting in a shallow, rough pit. This type of rock has a VSO between 13,000 and 15,000 fps and is considered hard rock by the construction industry.

Rebound-Quality rock material has no "reaction" to impact. It is a true "brittle-elastic" substance. This type of rock has an estimated VSO higher than 15,000 fps. Breakage is often sharp and angular because of the rock's brittleness. It also has a very high energy transfer in response to blasting. The burden and spacing can be increased when blasting in this type of rock.

The Mineral Grain Bonding Element Classification allows unconfined, compressive strength to be correlated with VSO:

MBL (Moldable): No blasting required

CQ (Crater Quality): VSO = 8,000 to I0,000 fps

DQ (Dent Quality): VSO = 10,000 to 13,000 fps

PQ (Pit Quality: VSO = 13,000 to 15,000 fps

RQ (Rebound Quality): VSO = 15,000 fps and higher.

Overlap between elements is immediately apparent. There is also an overlap in the actual responses to the hammer test. The estimate will be somewhat subjective, but with only a little practice and care a Blaster can make a remarkably accurate determination of VSO.

Determination of Specific Gravity—The specific gravity of rock can also be estimated by the URCS method:

MBL .... 1.7 to 2.1
CQ ...... 2.2 to 2.3
DQ ...... 2.4 to 2.5
PQ ...... 2.5 to 2.6
RQ ...... 2.7 to 3.0 and higher.

A simple method can be used to directly measure specific gravity in the field. This procedure should be used at least once to verify the URCS hammer-blow tests. A hand scale, a wire with a loop to hang the rock from the scale, and a bucket of water are all that is needed. Simply weigh the rock hanging from the scale, then submerge the rock in water and weigh it again.

Use the formula:

$$SG = \frac{W_a}{W_a - W_w}$$

where SG = Specific gravity
W_a = Weight in air
W_w = Weight in water.

Table 7.1 shows some typical examples of properties of materials important to Blasters.

Table 7.1 Properties of various materials.

Material name and Location	Sonic velocity (fps)	Specific gravity (gm/cc)
Air	1,080	0.0012
Aluminum	21,500	2.70
Basalt (MI)	15,200	2.85
Basalt (NY)	19,000	2.94
Clay	3,700 to 8,200	1.40
Concrete	11,700	2.7 to 3.0
Dolomite (TN)	17,900	2.84
Dunite	26,200	3.28
Gabbro	21,500	2.98
Gneiss	15,500 to 18,300	2.65
Granite (GA)	8,900	2.64
Granite (NC)	8,000	2.60
Granite (VT)	11,100	2.66
Gypsum	7,000 to 12,000	2.30
Ice	11,000	0.9
Iron	19,000	7.85
Limestone (IN)	12,400	2.31
Limestone (OH)	15,500	2.69
Limestone (WV)	16,400	2.68
Marble (MD)	13,700	2.37
Marble (NY)	14,500	2.72
Quartzite (MN)	18,200	2.75
Rubber	3,400	1.15
Sand	4,600	1.93
Sandstone (AL)	12,500	2.76
Sandstone (OH)	5,600	2.06
Sandstone (WV)	12,900	2.50
Schist	14,900	2.80
Shale (UT)	14,900	2.81
Shale (WV)	13,600	2.40
Slate	12,000 to 14,600	2.80
Soil	500 to 2,500	1.1 to 2.0
Steel	20,000	7.70
Till	1,300	1.5 to 2.0
Water	4,750	1.00

7.3 Rock Fracturing

Other important rock characteristics affecting the blast are bedding planes, jointing, and fracturing (Figures 7.2 and 7.3):

* Blast energy can escape through the open joints and fractures.

* Massive rock breaks differently than fractured, closely spaced rock.

Figure 7.2—Narrow fractured bedding planes.

Figure 7.3—Rock that fractures in a blocky fashion.

* Existing planes of weakness affect the size of the rock produced.

* Stability of blasted slopes is affected by joint spacing and orientation (dip patterns).

Joints and fractures can be observed and their spacing can be measured. A clinometer can be used to measure the inclination of the joints relative to a blasted slope, known as dip patterns.

Large blocky rock patterns often require smaller drill sizes and more holes to reduce oversize material. The extra holes distribute the energy of the explosive more evenly through the rock mass.

Planes of weakness that cannot be detected visually are referred to as latent planes of weakness. A 5-pound single jackhammer is a good tool to determine planes of weakness. The rock can be hammered to determine if it breaks readily on impact.

On small road blasting projects the Blaster can draw a cross-section of the blast area (Figure 7.4) to determine the possibility of rock failure because of dip patterns. The cut slopes can be often modified to follow any problem bedding planes. If the slopes are high, creating the potential for safety problems, an engineering geologist should be consulted.

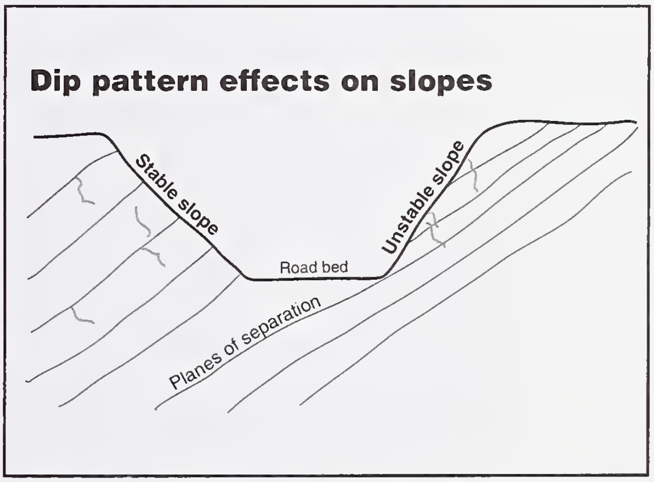


Figure 7.4—The orientation of dip patterns in road cuts can create unstable slopes.

Figures 7.5 and 7.6 are examples of a quarry map and development specifications.

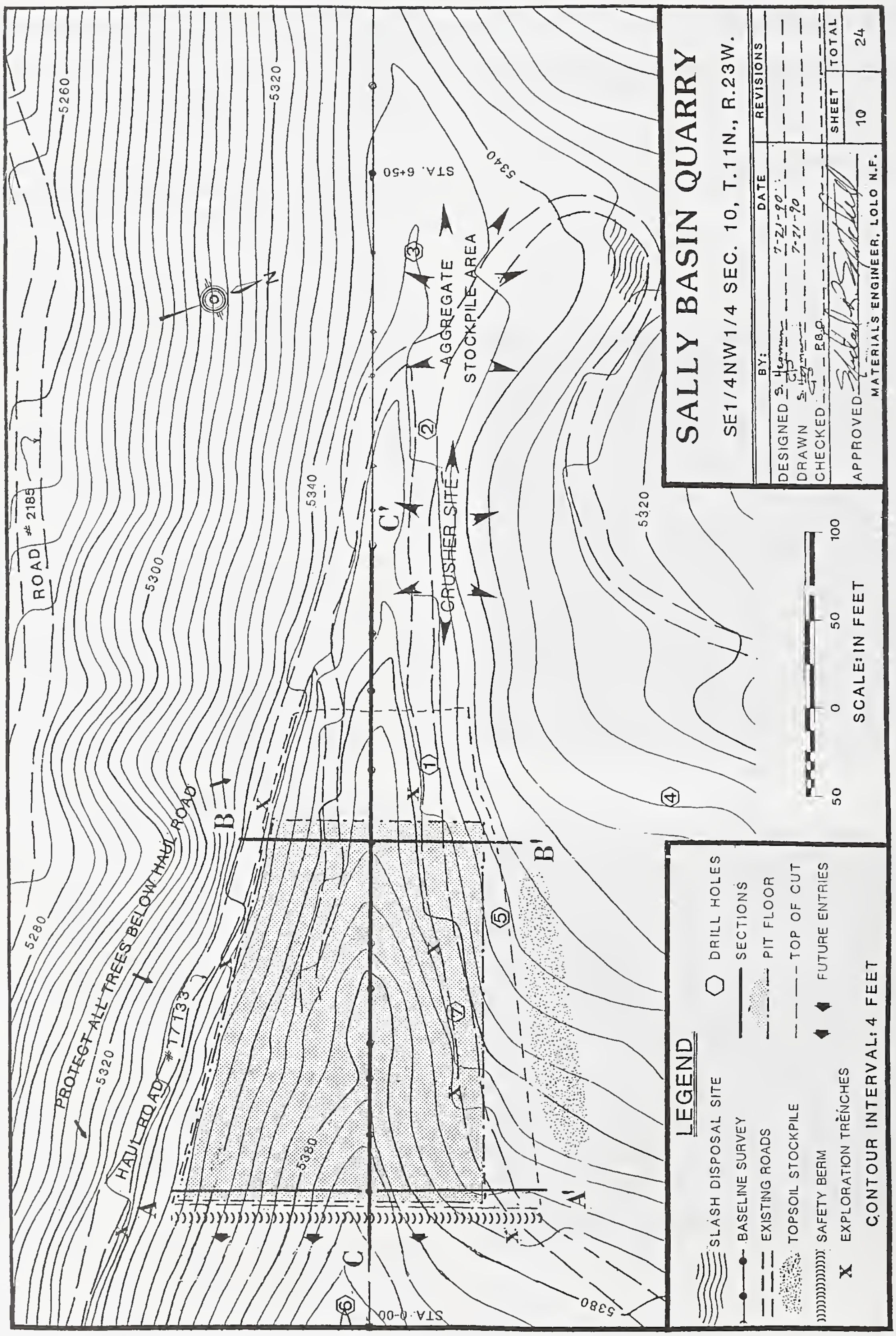


Figure 7.5—Sally Basin topographic map showing quarry development requirements.

SALLY BASIN QUARRY: DEVELOPMENT REQUIREMENTS

BLASTING REQUIREMENTS:

A. THE CONTRACTOR IS RESPONSIBLE FOR ALL BLASTING PLANS AND THE RESULTS OF THE BLASTINO OPERATION.

B. PRIOR TO DRILLING, THE CONTRACTOR SHALL SUBMIT A BLASTINO PLAN TO THE FOREST SERVICE FOR REVIEW. SUBMISSION OF THE BLASTING PLAN DOES NOT RELIEVE THE RESPONSIBILITY OF THE CONTRACTOR TO PRODUCE RESULTS CONFORMING TO THE SPECIFICATIONS.

C. THE BLASTING PLAN SUBMITTED TO THE FOREST SERVICE SHALL INCLUDE: REFERENCED LOCATION, AREA, DEPTH, AND VOLUME OF SHOT; DIAMETER, SPACING, DEPTH, INCLINATION AND NUMBER OF ROWS OF DRILL HOLES; TYPE, STRENGTH, AMOUNT, CONFINED VELOCITY AND DISTRIBUTION OF EXPLOSIVES AND PRIMERS TO BE USED; THE PATTERN AND SEQUENCE OF DELAYS; DATA PERTAININO TO THE TEST BLAST. THIS INFORMATION SHALL BE SUBMITTED IN A LEGIBLE AND ORGANIZED FORMAT TO THE ENGINEER AND SHALL BE AMENDED TO INCLUDE ANY ADJUSTMENTS DEEMED NECESSARY AFTER THE TEST BLAST.

D. A TEST BLAST SHALL BE REQUIRED PRIOR TO BLASTING OR WHEN A SIONIFICANT CHANOE IN ROCK MATERIAL IS ENCOUNTERED. THIS REQUIREMENT MAY BE WAIVED IN WRITING WHERE, IN THE JUDGEMENT OF THE ENGINEER, ROCK STRUCTURE (JOINTS, SEAMS OR FRACTURES) AND SUCCESS OF PRIOR BLASTS INDICATES NO PROBLEMS EXIST.

E. THE TEST BLAST IS PART OF THE OVERALL BLASTING PLAN AND SHALL BE INCLUDED IN THE MASTER BLASTING PLAN. IT SHALL BE NO LARGER THAT 10% OF THE VOLUME OF MATERIAL TO BE EXCAVATED AND SHALL BE NO SMALLER THAN NECESSARY TO PRODUCE REPRESENTATIVE RESULTS.

F. WHERE DAMAOE OUTSIDE THE EXCAVATION LIMITS OCCURS OR SUITABLE FRAGMENTATION IS NOT ACHIEVED, A REDESIGN OF THE BLASTINO PLAN AND A SUBSEQUENT TEST BLAST WILL BE REQUIRED PRIOR TO CONTINUATION OF THE BLASTING OPERATION.

DEVELOPMENT QUANTITIES: ITEM 611

QUARRY DEVELOPMENT AND HAUL ROAD CONSTRUCTION SHALL BE TO STANDARD FOREST SERVICE SPECIFICATIONS.

DESCRIPTION:	QUANTITIES:
CLEARING (PIT AREA & HAUL ROAD).............	3.05 ACRES
EXCAVATION (HAUL ROAD)......................	5.724 C.Y.
HAUL (HAUL ROAD)............................	17,122 S.Y.
TOPSOIL (PIT AREA & CRUSHER SITE)...........	1,723 C.Y.
EXCAVATION (CRUSHER PAD BORROW)	1,200 C.Y.
EXCAVATION (DRAIN DIP)......................	ONE
AGGREGATE (HAUL ROAD).......................	329 C.Y.
18" CMP (SPEC. 603, METHOD C)...............	36 LIN. FT.
SEEDING (PIT, CRUSHER SITE, HAUL ROAD).......	2.73 ACRES
METAL GATE (HAUL RD., SEE SHEETS 14 & 15)...	ONE

PIT DEVELOPMENT NOTES:

1. A CRUSHER SITE PLAN (INCLUDING AGGREGATE STOCKPILE AND WEIGH HOUSE LOCATIONS) SHALL BE SUBMITTED TO THE ENGINEER FOR APPROVAL PRIOR TO BEGINNING OPERATIONS.

2. PIT DEVELOPMENT SHALL CONFORM TO SPECIFICATION 611, "DEVELOPMENT OF PITS AND QUARRIES".

3. CUT SLOPES SHALL BE LEFT AS SHOWN ON THE PLANS UNLESS OTHERWISE APPROVED BY THE ENGINEER. NO SLOPES SHALL BE LEFT IN A DANGEROUS CONDITION.

4. PIT DEVELOPMENT SHALL INCLUDE CONSTRUCTING SAFETY BERMS AND BENCHES AS SHOWN ON THE DRAWINGS.

5. THE QUARRY FLOOR SHALL BE SLOPED AS SHOWN ON THE PLANS.

6. UP TO 500 CUBIC YARDS OF OVERSIZED ROCK MAY BE STOCKPILED FOR USE AS RIPRAP AT AN AREA DESIGNATED BY THE ENGINEER.

7. CLEARING LIMITS SHALL BE 5' FROM TOP OF CUT.

8. LOGS MEETING UTILIZATION STANDARDS SHALL BE DECKED AT A LOCATION DESIGNATED BY THE ENGINEER.

9. TREES BELOW THE HAUL ROAD SHALL BE PROTECTED FROM DAMAGE.

11. EXCEPT FOR THE ROAD CONSTRUCTION SHOWN ON SHEET #9, NO CONSTRUCTION ACTIVITY OR SIDE-CASTING OF MATERIAL WILL BE PERMITTED ON THE SW SIDE OF THE HAUL ROAD.

12. ALL AVAILABLE TOPSOIL WITHIN THE AREAS TO BE DISTURBED SHALL BE STRIPPED, STOCKPILED AND REPLACED TO A MINIMUM 6" DEPTH WHERE SHOWN ON THE DRAWINGS.

13. SITE RECLAMATION SHALL INCLUDE SMOOTHINO, SHAPING AND SLOPING OF ALL AREAS DISTURBED DURING CRUSHER OPERATIONS.

14. ALL AREAS DISTURBED DURING OPERATIONS SHALL BE SEEDED IN ACCORDANCE TO ITEM 625

15. THE GEOLOGIC REPORT AND DRILL AND TEST TRENCH LOGS WILL BE AVAILABLE UPON REQUEST THROUGH THE CONTRACTING OFFICER.

Figure 7.6—Site preparation specifications for Sally Basin quarry.

Chapter 8—Drilling and Field Control (RESERVED)

Chapter 8: Updated information for this section of this guide was not available when this document was printed. Anyone using this guide for training purposes should obtain the latest information from the resources listed in the *References* section.

Chapter 9—Blast Design

9.1 General

Numerous authors have developed approaches to blast design based on a combination of engineering, science, and experience. These approaches have served the purpose for specific projects such as rock blasting, quarry development, road construction, mining, and demolition. The blast design process can be very confusing to the new Blaster. Results can vary from successes to disasters. Blasting activities may produce little airblast, no flying rock, and minimum ground vibration, or they may spew large amounts of soil, debris, and rock with an airblast that extends for many thousands of feet.

Designs for blasting activities can be quite different. Typically, designs are controlled by limitations that are imposed by ground vibration, airblast, the drill sizes that are available, the powder that is available, and the budget for the project—not by the most efficient way to use explosives. For example, portable drills used in remote locations for small jobs will typically drill a hole $1\frac{3}{8}$ inches in diameter. Drill steel usually can be no longer than 2 feet (4- and 6-foot drill steel is sometimes packed into the backcountry on mules).

Blast designs for projects relying on portable drills must be based on the limitations of that equipment (for instance, the spacing and burden will typically be restricted to about 18 inches). In a location where rock breakage and throw is more important than ground vibration and airblast limitations (such as mining operations located miles from any town), it might be practical to use more explosives than normal. Compare such cases to breaking rock next to a structure in a downtown area where ground vibration and airblast must be held to absolute minimums. Despite such a variety of constraints, well-designed blasts will cause less damage to resources and use explosives more efficiently, saving large sums of money associated with drilling, crushing, and resource damage.

9.2 Rock Blasting Design

Blast design begins with site-specific information. Sometimes blast design begins with a predetermined hole diameter (usually because of the available drill size or because a contractor wants to drill a few large holes instead of many small holes). Calculations of blast geometry are based on that specification (Figure 9.1). In any case, knowledge of rock geology, structure, density, strength, and site conditions are needed to base a design on the three key explosives performance factors: energy distribution, energy confinement, and explosive energy level.

9.2.1 Energy Distribution

For consistent fragmentation, the explosive energy must be evenly distributed within the rock mass. Proper energy distribution is achieved by using a charge diameter that is appropriate for the bench height, selecting the proper burden

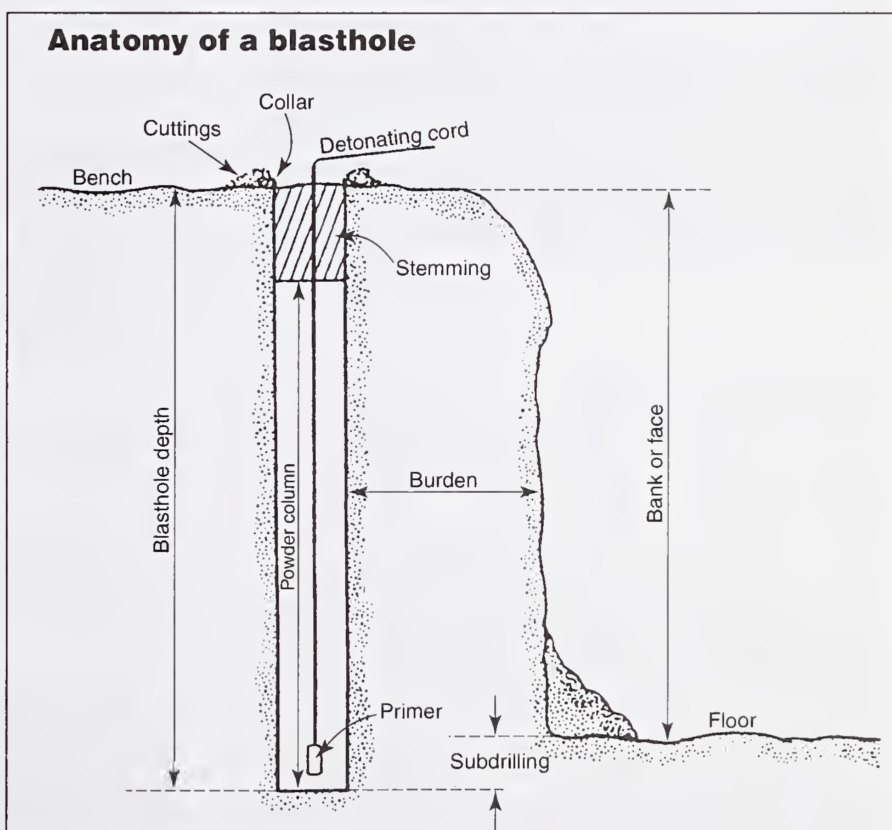


Figure 9.1—Typical rock-blasting layout.

and hole spacing dimensions, having reasonably uniform structure (especially adjacent to any free face), and drilling accurate holes.

9.2.2 Energy Confinement

Gas pressure must be confined long enough to do its job if it is to adequately fragment and displace a rock mass after the initial shock from an explosive blast. If the blast is not confined properly, large airblasts and flyrock can be expected. Proper energy confinement is done by selecting proper burden and hole spacing dimensions; by using proper stemming procedures, dimensions, and material; and by using appropriately timed detonations. Explosives should not be loaded into cracks, voids, or weak seams.

9.2.3 Explosive Energy Level

The proper explosive energy level is the amount of energy needed to break and heave rock efficiently. This may be referred to as the *powder factor*. The characteristic powder factor depends on the geological properties of the rock mass being blasted, the density of the explosive being used, and the detonation velocity of the explosive. A Blaster must begin by evaluating and selecting explosives that will provide optimum breakage for a given geologic site.

9.2.4 Rules of Thumb

* The explosive's detonation velocity should match, as closely as possible, the sonic velocity of the rock being blasted. There is a relationship between rock density, rock strength, a rock's sonic velocity, and the energy needed to crack and break rock. The denser the rock and the higher the sonic velocity, the more energy will be needed to break and move the rock. The Unified Rock Classification System can be used to determine the sonic velocity of a given rock (Chapter 7, Geological Effects on Blasting).

* Always select the densest explosive, consistent with its water resistance, the loading conditions, and the final cost. The denser the explosive, the more weight that can be put in a given borehole size. Hole spacing can be increased if the explosive has a higher density.

* Select explosives according to the characteristics of the rock formation being blasted. In cases where the formation is characterized by numerous planes of separation (schist layers) that are smaller than the required fragmentation, the rock can be blasted with a low-detonation-velocity explosive such as ANFO (less costly than higher velocity watergels or emulsion blends). The confinement pressure will do the work by displacing the rock (also known as bumping).

* When using slurry or watergel explosives, always determine the critical temperature below which the explosives will not detonate reliably. Most slurry explosives have a critical temperature below which they will not detonate or may not sustain detonation in boreholes. For watergels, this temperature may be around 30 °F. For emulsions this temperature is closer to 0 °F. Always consult the manufacturers' data sheets and consider the water temperature in the borehole, especially during the winter.

* Powder factors (PF) should range from 0.4 to 1.8 pounds per bank cubic yard (Table 9.1). The characteristic powder factor (CPF) for a blast design should range from 0.75 to 1 (pound per cubic yard) when shooting to a free face.

If the characteristic powder factor is over 1 pound per cubic yard when shooting to a free face, the explosive used in the calculations is not dense enough or doesn't have a high enough detonation velocity for the rock being blasted.

Table 9.1—Typical powder factors for surface blasting.

Degree of difficulty in rock breakage	Powder factor (lb/bank cu yd)
Low	0.25 to 0.40
Medium	0.40 to 0.75
High	0.75 to 1.25
Very high	1.25 to 2.50

If the characteristic powder factor is less than 0.75 pounds per cubic yard when shooting to a free face, the explosives used are too dense or have too high a detonation velocity for the rock being blasted.

In blasts where there is no free face and one must be created by the use of delays, the characteristic powder factor should be between 1.25 and 1.5 pounds per cubic yard. Initially, the free face created by the detonation of the shorter delays will be the area that receives the rest of the shot as the rock

expands. It is always best to develop a free face to shoot to because the open area beyond the free face allows for expansion (up to 18 percent) of the rock being blasted. If you fail to develop a free face to shoot to, large quantities of material may be cast downhill, possibly causing irreparable resource damage. A test shot should be conducted to determine if the design is appropriate. Free faces should be developed as soon as practical on the project.

✱ Always slit and tamp cartridge explosives to achieve maximum intimate contact (direct coupling) between the explosives and the rock to be blasted.

When cartridge explosives are simply placed in a borehole without slitting and tamping, a significant amount of shock energy is lost. A ¼-inch air gap will reduce the effective shock value of an explosive by up to 25 percent. We recommend that all explosives have as much intimate contact as possible with the surface being blasted. The recent advent of pourable slurries and emulsions has alleviated many of these problems. In small rock shots and mudcapping, maintaining intimate contact between explosives and the surface being blasted is important for effective rock blasting.

9.2.5 Blasting Geometry

Estimation of blast geometry typically includes six factors:

1—Burden selection (distance from the nearest hole to the free face). Burden is typically calculated at 25 to 35 times the diameter of the explosives charge, depending on site-specific conditions and requirements. For example, a 6-inch-diameter charge would typically have a burden range of between 12 and 18 feet.

A formula sometimes used by operators moving into a new area is: $B = ((2\ SGE/SGR) + 1.5)D$

where: B = Burden (ft)

SGE = Specific Gravity of Explosive

SGR = Specific Gravity of Rock

D = Diameter of Explosive (inches)

—From *Rock Blasting,* U.S. Department of Transportation, Federal Highway Administration

A 6-inch-diameter emulsion with an *SGE* of 1.3, in limestone with a *SGR* of 2.6 would have a burden of:

$$B = ((2 \times 1.3/2.6) + 1.5) \times 6 = 2.5 \times 6 = 15 \text{ feet}$$

2—Rock type, blastability, and effects on burden: When blocky rock types (hard rock) are encountered, the burden is generally reduced. Hole size must be reduced as well. In rock with blocky formations that are about 8 feet apart (seam to seam), holes could be drilled on 7- to 8-foot patterns in the middle of each block, distributing the blast's energy evenly throughout the entire mass. This will improve fragmentation and reduce the amount of rock that is too large to be used as fill (oversize). In soft or highly fractured rock (schist) the burden can often be expanded without adversely affecting the performance of the blast.

When strike-and-dip patterns (seams of planes of separation) run 45 degrees from horizontal or vertical, holes may have to be drilled at an angle to improve blast fragmentation and reduce backwall damage. The best blast results are when the strike pattern is at an angle to the free face.

3—Bench height (height from the desired grade to the surface): Once the burden dimension is estimated, it should be compared to the desired bench height. If the bench height divided by the burden dimension is less than two, the rock mass will be stiff and hard to displace horizontally. When blasting toward a free face, the bench height-to-burden ratio should be at least three to promote horizontal movement. If the rock mass has many layers (schist, shale, and similar rocks), it may be appropriate to reduce the bench height to minimize blowout in the middle of the column. Assume a hard, homogeneous solid rock structure for the following example: Bench height = 3 x burden; based on our earlier calculation of the burden, bench height = 3 x 15 feet = 45 feet.

4—Spacing (distance from hole to hole: The optimum spacing dimension will range from 1 to 1.5 times the burden. To achieve maximum energy distribution, the holes should be drilled on a staggered pattern and the spacing should be 1.15 times the burden.

Spacing (S) = 1.15 x Burden or 1.15 x 15 feet = 17 feet

5—Stemming (distance from the surface to the explosives): Stemming should equal 0.7 times the burden when good stemming material can be obtained and where confinement can be guaranteed in solid rock. In all other cases, stemming should equal the burden.

Stemming = Burden = 15 feet

6—Subdrill (distance below grade to which the borehole is drilled): Subdrilling should not be considered when it is important to protect the integrity of the rock below grade level. This would be the case for multiple bench final-wall control blasts or overburden coal mining. In most quarry applications, subdrilling is required to make sure the rock can be excavated all the way to the desired grade. Normally the subdrilling will range between 0.1 and 0.5 times the burden dimension or 0.4 times the largest dimension, which is usually spacing.

Subdrill = 0.4 x 17 feet = 6.8 feet

9.2.6 Calculating Characteristic Powder Factor and Powder Factor

Now that the explosives have been selected and the blast geometry has been estimated, the characteristic powder factor and powder factor can be calculated.

Characteristic Powder Factor—*CPF* is calculated using two independent values known as characteristic impedance (Z), and kilobars of detonation pressure (K)—or $CPF = Z/K$.

Z is calculated by: $Z = 1.31 \times SGR \times VSO/1000$
where: SGR = specific gravity of the rock
and: VSO = sonic velocity of the rock.

The characteristic impedance of limestone with a specific gravity of 2.5 and a sonic velocity of 15,000 ft per second is: $Z = 1.31 \times 2.5 \times 15{,}000/1{,}000 = 49.13$.

To calculate K: $K = 0.418 \times De \times (VOD/1000)^2 / (0.8 \times De + 1)$
where: De = density of explosive
and: VOD = detonation velocity of the explosive.

An explosive with a density of 1.25 that detonates at a velocity of 15,500 feet per second produces a detonation pressure of:

$K = 0.418 \times 1.25 \times (15{,}500/1000)^2 / (0.8 \times 1.25 + 1)$
$K = 125.53/2 = 62.77$ kilobars.

The characteristic powder factor is found by dividing Z by K: $CPF = Z/K = 49.23/62.76 = 0.78$.

When the CPF is between 0.75 and 1, the right explosive has been selected.

Powder Factor—*PF* is determined by dividing the charge weight (in pounds) per borehole by the volume shot (VS) per borehole: $PF = CW/VS$
where: CW = loading density times the charge length
and: VS = Volume shot per borehole.

Loading density is equal to:
Loading density = $0.3405 \times D^2 \times De$
where: D = explosive charge diameter
and: De = explosive density.

If the explosive diameter = 6 inches and explosive density = 1.3, loading density = $0.3405 \times 6 \times 6 \times 1.3 = 15.94$ pounds per foot.

Charge length (CL) is calculated as the bench height of 45 feet plus the subdrill of 6.8 feet minus 15 feet of stemming:
$CL = (BH + Sd - St) = (45 + 6.8 - 15) = 36.8$ feet.

The charge weight (CW) equals loading density times charge length: CW = 15.94 pounds/feet x 36.8 feet = 586.4 pounds per borehole.

Volume shot (VS, bank cubic yards per hole) = (Burden, B x Spacing, S x Bench Height, BH) divided by 27:
$VS = (B \times S \times BH)/27$.

In this example, $VS = 15 \times 17 \times 45/27 = 425$ bank cubic yards per hole.

The powder factor equals the charge weight divided by the volume shot: $PF = CW/VS = 586.4/425 = 1.38$ pounds per bank cubic yard.

Powder factors range between 0.4 and 1.8 pounds per bank cubic yard depending on rock type and structure, bench geometry, fragmentation required, and explosives energy distribution and confinement.

A reasonable starting point for powder factor is 0.9 pounds per bank cubic yard. In this example it may be advisable to decrease the density of the explosive from 1.3 to 1.0.

In summary: $PF = (0.3405 \times D \times D \times De) \times (BH + Sd - St) / (B \times S \times BH)/27$.

When using an explosive with a density of 1.0, the powder factor equals: $PF = (0.3405 \times 6 \times 6 \times 1) \times (45 + 6.8 - 15)/(15 \times 17 \times 45)/27 = (12.26 \times 36.8)/425 = 1.06$ (compared to 1.38).

The characteristic powder factor is also influenced by a change in explosive density (De): $CPF = (1.31 \times SGR \times VSO/1000)/ (0.418 \times De \times (VOD/1000)^2 / (0.8 \times De + 1)$.

Substituting the new value for density: $CPF = (1.31 \times 2.5 \times 15{,}000/1{,}000)/(0.418 \times 1 \times (15{,}500/1{,}000)^2/(0.8 \times 1 + 1)$.
$CPF = (49.125)/(100.42)/1.8 = (49.125/55.791) = 0.88$

Decreasing the explosive density increased the characteristic powder factor to 0.88 while decreasing the powder factor to about 1.06. These design values are more acceptable.

Another alternative might be to increase burden and spacing dimensions. Several iterations may be necessary before an optimum design can be selected. Blast designers are encouraged to consult other documents, consider other design techniques, rely on their own experience, and, most importantly, conduct test shots to ensure the design selected is the most appropriate. Constant monitoring that leads to slight changes in blast geometry or explosives selection can improve efficiency. A simple drill and blast planning data sheet can be used when designing blasts (Figure. 9.2).

DRILL AND BLAST PLANNING

Job____ Date____________________

Explosive diameter (inches)_______ Explosive density (g/cc)_______ Bench height (feet)_______

BURDEN	= $\frac{(25 \text{ to } 35) \times \text{hole diameter}}{12}$ Should be less than half of bench height for best fragmentation.	**BURDEN =**_______
SPACING	= Burden x 1.2	**SPACING =**_______
STEMMING LENGTH	= Burden x 0.7 Should be less than half of hole depth for best fragmentation.	**STEMMING LENGTH =**_______
SUBDRILL DEPTH	= Burden x 0.3	**SUBDRILL =**_______
BLASTHOLE DEPTH	= Bench height + Subdrill	**HOLE DEPTH =**_______
POWDER COLUMN LENGTH	= Hole depth - Stemming	**POWDER COLUMN =**_______
EXPLOSIVE LOADING DENSITY	= Explosive density x 0.3405 x Explosive diameter^2	**LOADING DENSITY =**_______ (lb per ft)
EXPLOSIVE WEIGHT	= Explosive loading density x Powder column length	**EXPLOSIVE WEIGHT =**_______ (lb per hole)
VOLUME SHOT (yd^3 hole)	= $\frac{\text{Bench height} \times \text{Burden} \times \text{Spacing}}{27}$	**VOLUME SHOT =**_______ (yd^3 hole)
POWDER FACTOR (lb/yd^3)	= $\frac{\text{Explosive weight}}{\text{Volume shot}}$	**POWDER FACTOR =**_______
PRESPLIT SPACING	= Hole diameter (inches) x 12	**PRESPLIT SPACING =**_______

Figure 9.2—The *Drill and Blast Planning* form.

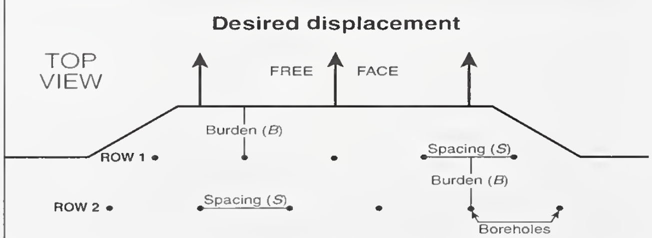
9.2.7 Timing Considerations

Developing efficient blast designs includes determining the delay interval between blastholes in a row and between rows of holes. Timing plays an important role in placement of the muck pile, which is typically parallel to the burden. Delay intervals between holes in a row are based on the distance between the holes. Typically, the delay ranges from 1 to 11 milliseconds per foot. A reasonable starting point for the delay interval between blasthole rows is 5 milliseconds per foot of burden. If the burden is 15 feet, the calculation would be: Delay intervals between rows = 15 x 5 = 75 milliseconds.

The delay interval between holes in a row of blastholes is generally one-third of the delay time between rows, or: Delay interval between holes in a row = 75/3 = 25 milliseconds.

Figure 9.3 shows another timing delay example.

Worksheet for delay interval timing



Note: The rows of boreholes are perpendicular to the burden and desired displacement.

To determine timing, you must know the burden and spacing.

Burden (*B*) can be determined by:

B (feet) = $[(ED \times 2 \div RD) + 1.8] \times CD$

ED = Explosive density; RD = Rock density; CD = Charge diameter

Example: $[(1.27 \times 2 \div 2.55) + 1.8] \times 3\frac{1}{2}$ in = 9.8 ft

Use *B* = 10 ft

Spacing (*S*) can be determined by:

S (feet) = Burden x 1.15

Example: 10 ft x 1.15 = 11.5 ft

Use *S* = 11.5 ft

To determine the delay interval between rows of boreholes with the delay interval being expressed in milliseconds (*MS*).

Delay interval between rows = Burden ft x 5 *MS*

Example: Burden = 10 ft x 5 *MS* = **50 *MS* delay interval**

To determine the delay interval between boreholes within a row—this is generally one-third the time between rows.

Delay interval between boreholes = MS x 0.33

Example: 50 MS x 0.33 = 16.5

Use 17 *MS* delay interval

Figure 9.3—Example worksheet of delay-interval timing between rows and holes.

Many publications are available from the manufacturers of detonation systems that provide examples of delay periods. These may be consulted for more elaborate layouts where the direction of throw can affect loading and hauling costs.

9.3 Small Rock Blasting Shots

Land management agencies face interesting challenges when rock outcrops (slab rock) must be blasted in remote locations. Consider a small trail-construction job several miles from any road where all tools and materials must be transported on packstock. These projects typically face tight restrictions on hole size, hole depth, and available powder. Because of timing and funding restrictions (mostly the latter), they will not be designed with the sophisticated formulas or tools available to most large-construction Blasters. Typically, holes $1\frac{3}{8}$ inch in diameter will be drilled in rock using a gasoline-powered drill (Ponjar or equivalent). Because drill steel is usually restricted to 2 feet, lifts will be restricted to 2 feet or less. Holes will be loaded with powder that is 1 inch in diameter and primed with det cord instead of using a detonator for each hole. Stemming becomes almost irrelevant because the detonating cord blows out the stemming before pressure builds up. The Blaster is relying on pure shock energy to break the rock. The burden and spacing dimensions are reduced to about 18 inches (Figure 9.4). Holes are overloaded, producing lots of airblast and flyrock.

Figure 9.4—Typical hole pattern and layout when using det-cord downlines in $1\frac{3}{8}$-inch holes.

The givens for this type of project are:
- Hole diameter = 1⅜ inches
- Hole depth = bench height = 2 feet
- Explosive diameter = 1 inch
- Explosive length = 1 foot
- Explosive specific gravity = 1 (typical of emulsions)
- Burden = spacing = 1.5 feet.

We can calculate the powder factor for this shot using the formulas from section 9.2.6: $PF = (0.3405 \times D \times D \times De) \times (BH + Sd - St)/(B \times S \times BH)/27$.

In this case there is no subdrill (*Sd*) or stemming (*St*). Bench height (*BH*) equals 2 feet. Since we are using a 1-foot charge length, ($BH + Sd - St$) becomes 1 foot, or:
$PF = 0.3405 \times 1 \times 1 \times 1 \times 1/1.5 \times 1.5 \times 2/27 = 2.04$.

The shot is overloaded. A shot that is overloaded to this extent will create excessive flyrock and noise. Increasing burden and spacing will decrease the powder factor. However, only about half of the energy available from the explosive is being used. Rock breakage cannot be assured.

We can calculate the characteristic powder factor to see if we reach a different conclusion. For this shot assume granite rock with a specific gravity of 2.64 and a *VSO* of 16,000 feet per second. An emulsion will be used that has a *VOD* of 16,000 feet per second and a density of 1.0 gram per cubic centimeter:
$CPF = Z/K = (1.31 \times SGR \times (VSO/1000))/(0.418 \times De \times (VOD/1{,}000)^2/(0.8 \times De + 1)$

$CPF = (1.31 \times 2.64 \times 16{,}000/1{,}000)/(0.418 \times 1 \times (16{,}000 / 1{,}000)^2/(0.8 \times 1 + 1)$

$CPF = 55.33/107/1.8 = 0.93$.

This *CPF* calculation shows that the shot is not overloaded. Note the importance of matching the detonating velocity of the explosive to the sonic velocity of the rock when relying on pure shock energy to break the rock.

The importance of good stemming is apparent from this example. If a Blaster is to shoot rock efficiently with little to no airblast and flyrock, each hole must have a detonator and be stemmed properly. This is very important when blasting slab rock in or around structures where airblast and flyrock might cause damage. Powder factors as low as 0.25 may be needed along with using blast mats and taking other protective measures.

Another factor on shots facing these restrictions is the insensitivity of watergels and emulsions when primed with detonating cord. Twenty-five-grain detonating cord will not initiate emulsions laterally when it passes through an explosive (Figure 9.5). Twenty-five-grain detonating cord initiates emulsions only marginally even when a knot is tied at the end of the cord so it will act as a booster. The old practice of lacing det cord through holes punched in the powder only serves to reduce the energy available for breaking rocks. All downlines should be 50-grain det cord with a knot tied at the end to promote detonation. The knot should be at the top of the explosives column (top priming). The trunkline can still be 25-grain cord that will reduce airblast and cost.

Lacing det cord through explosives

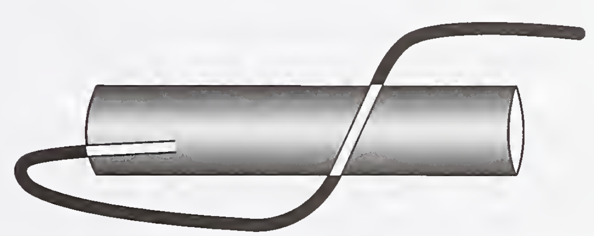


Figure 9.5—Lacing det cord through emulsions can cause misfires (deflagration) of the explosives.

A final consideration is the gap between the 1-inch-diameter powder cartridge and the 1⅜-inch borehole. A 25-percent loss in shock energy can be expected unless the explosive cartridge is slit and tamped to provide direct coupling between the explosive and the rock. One method to overcome this loss is to use water as a stemming material. Water is incompressible and transmits the shock wave to the rock more efficiently than air. This technique is very useful for crews using two-component explosives supplied in plastic tubes. Care should be taken not to degrade the explosive with water, reducing its shock energy and possibly causing deflagration or a misfire.

9.4 Single Rock Shots—Boulder Breaking

Road and trail crews often have to break large boulders that have fallen on roads or trails. The two common techniques used to break boulders are internal or external breaking. The internal technique requires drilling a hole in the boulder (Figure 9.6). External charges are simply placed on the surface of the boulder. Either technique can create large airblasts and lots of flyrock.

Internal charges require a drill hole

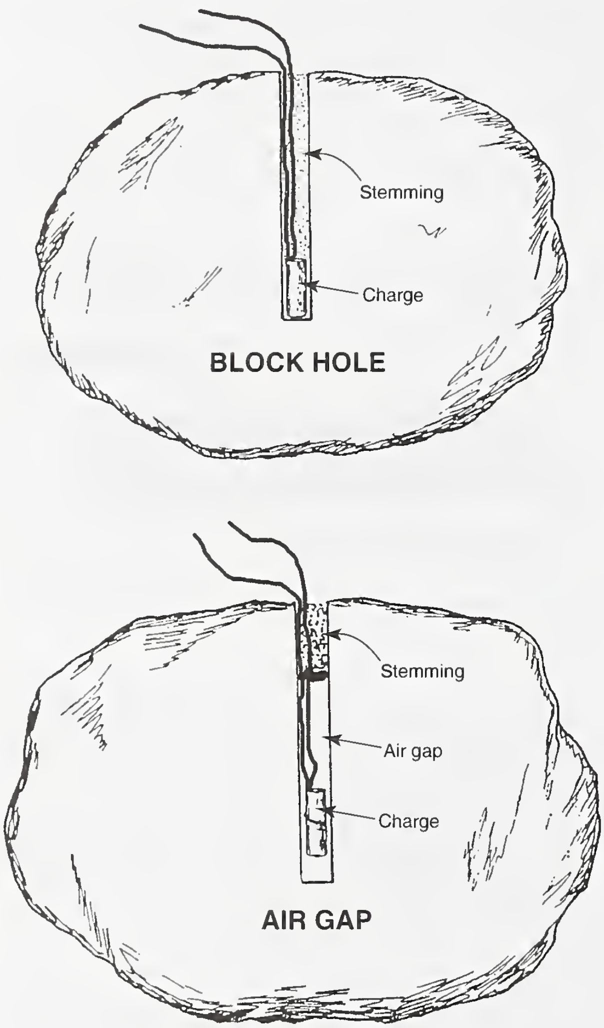


Figure 9.6—Internal boulder-breaking charges require a drilled hole.

9.4.1 Internal Charges

Most Forest Service units have a gasoline-powered drill (Ponjar or equivalent) that will drill 1¼- to 1⅜-inch-diameter holes. Pneumatic drills that are able to drill larger holes may be available. Holes should be drilled to at least the center of mass of the boulder. Using 2-foot drill steel restricts blasting to boulders no larger than about 4 feet in diameter. Larger boulders require more holes to ensure an even distribution of powder through the mass and may require longer drill steel. The boulder will generally break to the shortest dimension, which may be a seam or layer (plane of separation). If the hole is loaded with a single cap and sufficient stemming is used, the *characteristic powder factor* can be as low as 0.25. If no stemming is used, a *powder factor* of 2 may be required. Airblast and flyrock will be very high.

Design Considerations

Depth of holes—Holes should be no deeper than two-thirds the thickness of the boulder. If the holes are too close to the bottom of the rock, the charge may blow out of the bottom, leaving the top portion of the boulder cracked, but not broken. The idea is to get the explosive charge as close to the boulder's center of mass as possible.

Spacing of holes—When the boulder is bigger than 1.5 cubic yards, you may need to drill more than one hole. Always base the number of holes to drill on the boulder's largest dimension. If it is much wider than it is long, the width should be divided into thirds, which will require two holes, or into quarters which will require three holes. If the boulder is wide and long, but not very deep, the number of holes will increase even though the holes won't be very deep. The idea is to achieve equal distribution of the explosives throughout the mass.

Powder factor—Most boulders can be blasted with internal charges with a characteristic powder factor of between 0.25 and 0.5 pounds per cubic yard. The low powder factor is possible because the boulder has free surfaces on all sides that allow for reflection, breakage, and movement of the rock after detonation.

If the rock is buried in the ground with only the crown visible, a higher powder factor must be used because the rock is confined. The rock can only move up.

Type of explosives—If the rock has planes of separation, such as cracks or bedding planes, then low-velocity, low-density explosive is more than adequate. If the rock is solid, massive, and hard, a high-velocity, high-density explosive should be used (match *VSO* to *VOD*).

Note: Many holes are drilled with handheld drills, which make a rather small hole (1¼ to 2 inches). Do not use ANFO. The amount of ANFO that will go into the hole is minimal. The detonation velocity of ANFO in small-diameter holes is very low. In most cases, the primer charge that would be required to initiate the ANFO is more than sufficient to break the boulder.

Procedure—All blasting should be done systematically and carefully. This is the step-by-step procedure for breaking boulders:

1—Calculate the volume of the rock in cubic yards.

2—Determine the type and amount of explosive required.

3—Determine the number of holes required and mark their locations.

4—Drill the holes required.

5—Prime the explosive charge(s).

6—Load the charge(s).

7—Stem the remaining portion of the hole with sand, dirt, or drill findings.

8—Use a Blaster's galvanometer or multimeter to check the blasting cap for continuity.

9—Check the lead wire with the galvanometer.

10—Clear the area.

11—Give the proper warning signals.

12—Connect the lead wire to the blasting machine.

13—Detonate the blast.

CAUTION

The type of charge described in this section will reduce any boulder to manageable pieces. It will also cause flyrock. It is not unusual for charges of this type to throw pieces of rock several hundred feet. Covering the boulder with several feet of earth will hold down the flyrock—so will a blasting mat if it is available. An alternative method of blasting, the air gap method, will reduce flyrock.

Air Gap—The air-gap method of boulder blasting will significantly reduce noise and flyrock. The technique is similar to that for other internal charges, with the exception that only the top 15 to 18 inches of the borehole is stemmed.

A small charge is suspended in the borehole, about 6 inches from the bottom of the hole. A wad of paper or a rag is pushed about 15 inches to 18 inches into the hole to plug it. Damp sand or dirt is tamped in behind the plug to form a tight stem. At detonation, gases expand into the unstemmed portion of the borehole, creating enormous pressure in all directions. This pressure, plus the reflected and refracted shock fronts, breaks the rock. This technique allows a little bit of explosives to do a lot of work.

The powder factor should be no more than 0.25 pounds per cubic yard. It can often be less. The depth of the hole should be three-quarters through the boulder instead of two-thirds as with the standard internal charge. The resulting breakage is not usually as fine as with the standard internal charge, but it is more than sufficient for most purposes. This depth of the charge will open up the rock, much like an opening rose bud. If the powder factor is not excessive, flyrock should be minimal. Flyrock will tend to be blown in the direction from which the boulder was drilled. Noise is also reduced.

The air-gap technique requires a certain amount of practice. Laminated rock and rock with visible cracks or other latent or open planes of separation will break up very nicely with this technique. Massive boulders will break well with the use of the air gap, but they break in larger pieces than with the standard internal charge.

If the boulder is particularly massive, adding water to the borehole before stemming will help increase the fragmentation. A 3-cubic-yard boulder can be broken quite easily with a single hole in the center of mass when using the air-gap or water technique.

9.4.2 External Charges

Placing an external charge on a boulder is a technique used in many locations where a drill is not accessible and airblast will not present problems (Figure 9.7). An external charge should not be used within a mile of any residential area unless the resulting airblast can be discussed with local residents and appropriate protection measures can be taken.

Mud capping is one technique used to improve a shaped charge when using cartridge or bagged explosives. This technique allows better transfer of the shock wave to the boulder because air gaps and voids between the bagged explosives or cartridge and the boulder are filled with mud (soil and water). Water transfers shock energy much better than air. As much as possible, cartridges or bagged explosives should be stacked or shaped to create a pyramid or cone (Figure 9.7).

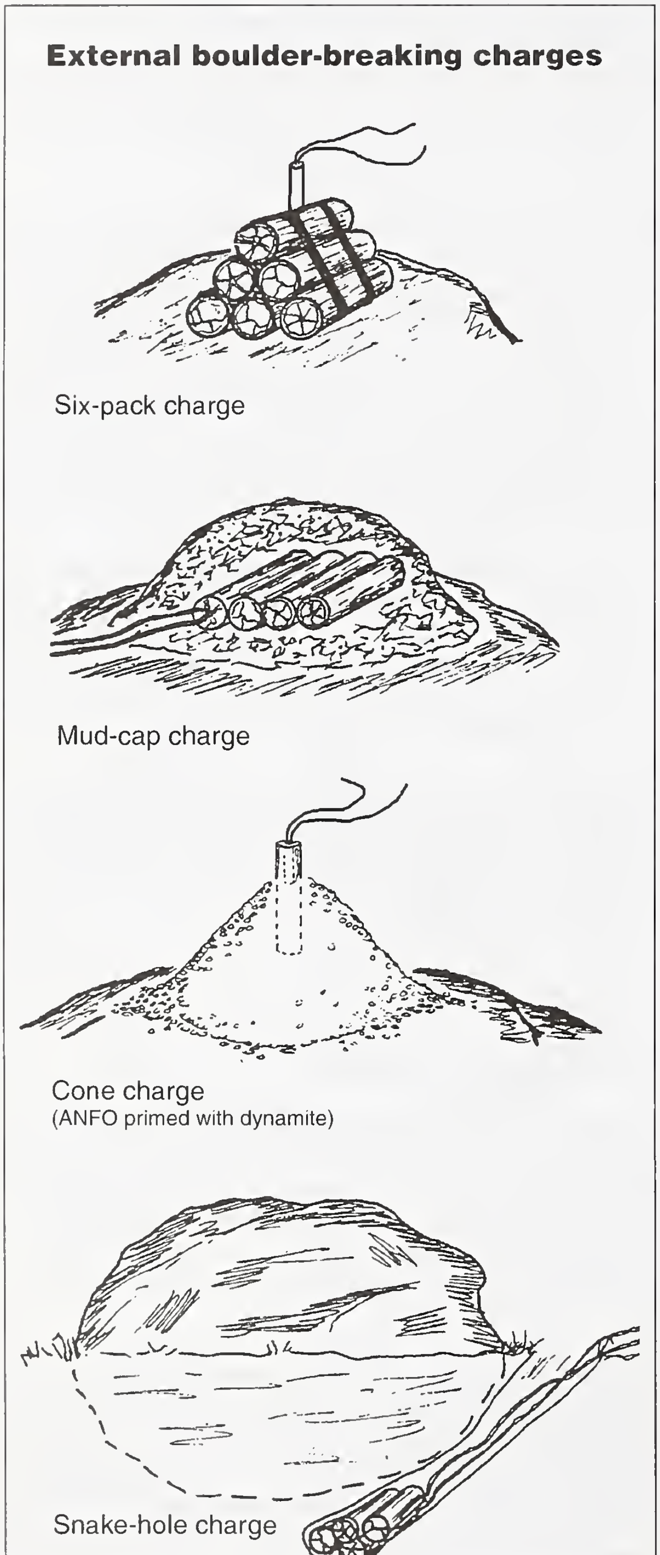


Figure 9.7—External boulder-breaking charges.

Five factors to consider when planning to break boulders with external charges are: rock structure, shape of the charge, point of initiation of the charge, position of the charge on the boulder, and proximity of the rock to structures and people.

Structure of the Rock—Rock structure can be very important when breaking boulders with external charges. This is particularly true when the rock has two-dimensional planes of separation, either latent or open. If the charge is detonated parallel to the lines of separation in a boulder, the rock may break along one or two of the planes, leaving great slabs of unbroken rock. The closer the planes, the worse the problem. The planes of mica schist are often as close together as pieces of paper. Blasting mica schist parallel to the planes is an exercise in futility. Turn the explosives on the rock 90 degrees, and the rock will come apart very easily.

Shape of the Charge—The shape of an external charge has a tremendous effect on the overall results of a detonation. With the exception of some military explosives, packaged explosives are cylindrical. Shaping any explosive charge into a cone formation and placing the detonator at the top allows the detonation wave to build from the cap (about ¼ inch) to the base of the cone (about 12 inches), transferring the maximum shock into the boulder. The detonator needs to be centered in the apex of the cone and be perpendicular to the base of the cone for maximum effect. Most boulders can be adequately broken with about 2 pounds of explosive per cubic yard of rock with this technique. If the boulder is buried in damp, compact soil or in water, more explosives will be required.

The ideal relationship between the base of the cone and height of the cone is a ratio of 2 to 1. The height of the cone should be one-half the diameter of its base.

Point of Initiation—The position of the initiation device, whether it is a blasting cap or the end of detonating cord, is vital to proper functioning of any external charge. The point of initiation should be as far from the end of the charge as is possible to ensure that the detonation front travels through the mass of the explosive. In a cone charge, that point is at the apex of the cone. The cap should be fairly straight up and down and firmly seated in the explosive. If the cap is canted from vertical, blast effect and fragmentation are significantly reduced.

Placement of the Initiator—If the cap is placed beneath the charge or in direct contact with the boulder, the breakage will usually be incomplete.

Using a standard of 2 pounds of explosives per cubic yard of rock for all charges, at least 150 percent better breakage is achieved when the cap is properly placed.

Position of the Charge on the Boulder—The base of the cone charge should be aimed as directly as possible at the center of the mass of the boulder.

Using ANFO to Break Boulders—The common belief that ANFO cannot be used unless it is confined is erroneous. All blasting agents must be heavily primed to obtain detonation. ANFO is difficult to initiate with detonating cord. If ANFO is primed as recommended, it makes an excellent and inexpensive cone charge.

The procedure for making a cone charge with ANFO is:

1—Clean dirt, moss, and other materials from the surface of the rock.

2—Slowly pour ANFO from the bag in which it is packaged onto the rock. The ANFO will form a conical shape. The degree of slope is called the angle of repose.

3—When 2 to 2.5 pounds of ANFO per cubic yard of rock is on the boulder, insert one primed stick of 1¼- by 8-inch explosive into the center of the apex of the cone. Push it well into the cone. Leave about 1 to 2 inches of the stick showing above the cone.

4—Insert a blasting cap or the end of a detonating cord line into the stick of explosive at the top of the stick. Recenter the stick in the cone, if necessary.

5—Proceed with standard safety procedures and fire the shot.

If it is raining, or if the ANFO might get wet from water that is standing on the rock, pour the ANFO into a plastic bag, place the bag on the rock, and mold the mass into a conical shape. Punch a hole in the plastic at the top of the cone, insert a primed stick of explosive as recommended above, and proceed with the shot.

If the ANFO cone charge is to be initiated with two-component explosives, the procedures are the same as above, with the following exceptions:

1—Form the ANFO cone charge on the rock.

2—Mix about 1 pound of the two-component explosive.

3—Flatten out the top of the ANFO cone by hand.

4—Pour the two-component explosive onto the flat portion of the cone, and mould it into a conical shape.

5—Prime the two-component explosive with a blasting cap or detonating cord, making sure that the initiator is pointed straight into the cone and is centered at the apex.

6—Proceed with proper safety procedures and fire the shot.

Two-Component Cone Charges—Cone charges can be made from two-component explosives in the same manner as ANFO. No additional priming is required because two-component explosives are already sensitive to blasting caps. Mold the cone by hand into the proper shape.

Emulsion Cone Charges—Most emulsions are packaged in sticks. It is difficult to make a cone charge with them. Under most circumstances, emulsion should not be taken from its packaging because the packaging materials may be part of the explosive's ingredients. If there is no alternative, emulsion cartridges may be unwrapped and molded into a cone. It is much easier to use the sticks themselves. Since cylindrical sticks won't make a cone, they must be formed into the next best thing—a pile of sticks with a triangular cross section. This is called a "six-pack" charge. For example, if 3 pounds of emulsion are needed to break a boulder, six sticks of 1¼- by 8-inch emulsion would be used. To make a six-pack, put three sticks on the bottom row, two sticks on the second row, and one stick on the top, with all the sticks pointing the same way. To maintain the configuration of the charge, secure the sticks with tape. To prime the charge, place the cap in the top stick in the pile. Putting the cap in the center of the top stick with the base of the cap pointing straight down into the triangle of sticks seems to produce the best results.

If additional charge weight is needed, add more sticks to form a bigger triangle. If the number of sticks called for does not form a proper triangle, add one or two more to make the triangle. A little extra charge doesn't hurt.

Determining the proper amount of explosives to use and the correct placement of the charge on the boulder becomes easier with experience. A good starting point is to figure about 2 pounds of explosive per cubic yard of rock. ANFO cones and emulsion six-packs may require slightly more explosive. Solid cones of high-velocity explosives will require slightly less.

Chapter 10—Specialty Blasting

10.1 Ditches and Wildlife Ponds

10.1.1 General

Sometimes heavy equipment cannot be used to dig ditches because the soil will not support the equipment's weight. Explosives are an obvious alternative. Using explosives in such situations is fast, efficient, and usually costs less than using machinery.

Noise, flyrock, and airblast are problems associated with the use of explosives for ditching. Building a ditch requires casting material from the ditch's route. This cannot be accomplished without making noise and throwing material.

Two methods of creating ditches with explosives are sympathetic detonation (not recommended) and charge-for-charge initiation (simultaneous).

Sympathetic Detonation—Sympathetic detonation uses the shock wave from the detonation of one charge to detonate other charges (Figure 10.1). The distance between charges is critical. The distance at which one charge will not detonate another charge is the gap sensitivity of that explosive. An explosive with a short gap sensitivity is not a good choice for sympathetic detonation. If the gap sensitivity is longer, the explosive lends itself to sympathetic detonation. In the early days of blasting, all dynamite was nitroglycerin or straight dynamite. The percentages noted on the cartridges indicated the percentage of the total weight that was nitroglycerin. Since nitroglycerin is very sensitive to shock, the early use of dynamites for ditching required no special attention to gap sensitivity. As the science of explosive design progressed, other chemicals replaced much of the nitroglycerin in dynamite. Modern dynamites contain far less nitroglycerin and also include substances that reduce their sensitivity to detonation. When relying on sympathetic detonation, use dynamites specifically designed for ditching. These dynamites have from 20- to 60-percent nitroglycerin. They are called ditching dynamites.

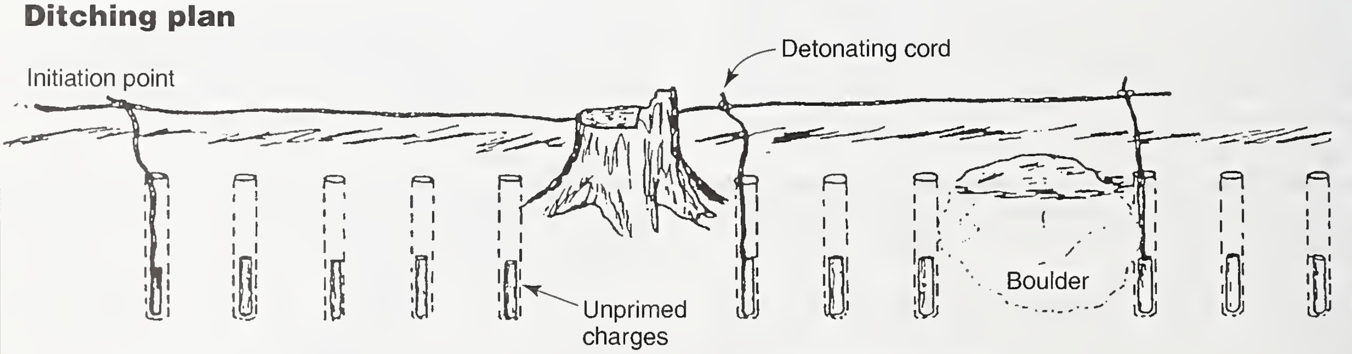
Charge-for-Charge Initiation (Simultaneous)—Charge-for-charge initiation means that each charge must be initiated individually (Figure 10.2). While this type of initiation can be accomplished by priming each charge with a blasting cap, it is more economical and takes far less time to use det cord. Charge-for-charge initiation must be used when explosives such as ANFO, watergels, or emulsions are used. Because soil characteristics play such an important role in sympathetic detonation, charge-for-charge initiation is the recommended method.

Firing all charges simultaneously produces the best ditches. There is no need to use delay blasting in any ditching procedure. If electric caps are used in charge-for-charge initiation, or in repriming the line where obstructions are encountered, instantaneous caps should be used. If these are not available, all caps should have the same delay period. Det cord detonates so quickly that no consideration of the slight delay needs to be considered.

Effects of Soil—The single most important factor is the condition of the soil to be blasted. The determination of the type of charge to be used is subjective. However, some criteria can be used to help make the determinations. Most soil will fall into—or close to—one of the following categories:

- Very wet and clear
- Very wet and obstructed
- Wet and clear
- Wet and obstructed
- Damp and clear
- Damp and obstructed
- Dry and soft
- Dry and dense.

Ditching plan



Multiple priming around obstructions in a ditch line

Figure 10.1—Blast plan for ditching using explosives.

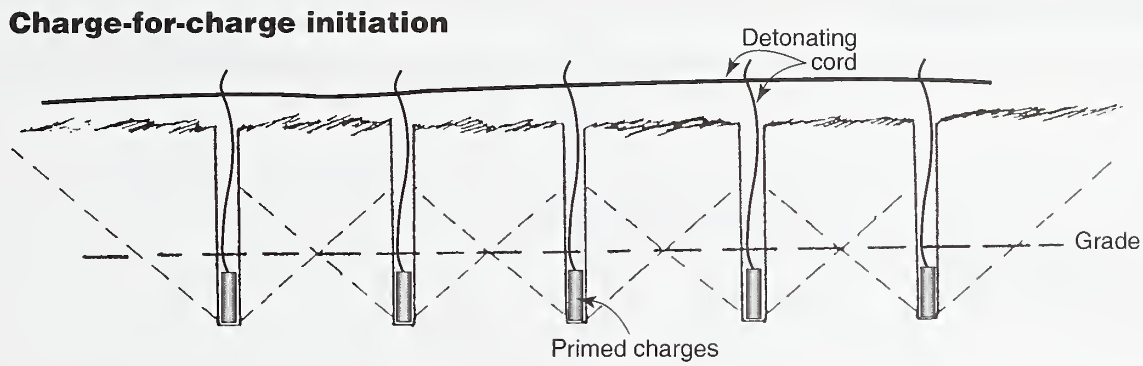


Figure 10.2—Each charge is initiated individually with detonating cord.

Very wet and clear means that the soil will barely hold the weight of a person. There are no obstructions such as dry patches, stumps, boulders, and root systems.

Very wet and obstructed means that the soil will barely hold the weight of a person, and there are one or more obstructions. These obstructions pose a problem when sympathetic detonation is used. If something obstructs the shock wave, all charges beyond the obstruction will fail to detonate. In such cases, charge-for-charge initiation must be used, or additional priming will be required for charges beyond the obstruction. In very wet soil 20- to 30-percent nitroglycerin ditching dynamite can be used.

Wet and clear means that the soil is wet, but will readily support persons and light equipment. No obstructions other than small stones or small rock are present. For sympathetic detonation, use ditching dynamite with more than 30-percent nitroglycerin. With wet and obstructed soil, additional priming will be required at each obstruction.

Damp and clear soil is drier than wet soil. Sympathetic detonation should not be used in damp soil. Charge-for-charge initiation will ensure proper initiation of all charges, and will produce the proper ditch. Use a low-velocity, low-density explosive such as ANFO.

Dry and soft soil includes such materials as loam, soft sand, and previously backfilled areas. Charge-for-charge initiation is required. Since the material to be blasted has little cohesion, it will readily absorb and dissipate shock waves. It must be “lifted” rather than shocked. Use a low velocity, low-density explosive (ANFO).

Dry and dense soil, clear or obstructed, requires charge-for-charge initiation and a higher velocity, higher density explosive.

Blasting Patterns for Ditches and Ponds—For smaller ditches (3 to 4 feet wide and about 3 feet deep), a single row of charges placed in holes about 15 to 18 inches deep and simultaneously detonated, should produce the desired results. If a wider ditch is required, two rows of holes will produce a ditch that is not quite twice as wide.

To increase a ditch’s depth, the charges should be placed deeper in the soil. In general, the bottom of the charge should be about 6 to 8 inches below the desired grade. The hole should be filled with explosives to within 8 to 12 inches of the surface, and stemmed with the material from the hole. In the case of very wet soil, water will fill the hole and serve as stemming.

As the hole depth and charge weight increases, the angle of the cone and the width of the ditch increase. It is nearly impossible to blast a ditch 8 feet deep and 3 feet wide. To determine about how wide the ditch will be at a given depth, draw a cone on graph paper with an angle of 120 degrees at the bottom of the cone (Figure 10.3). Follow the sides of the cone up the graph paper to the height of the ground surface. Measure across the cone at the surface. This is the approximate width of the resulting ditch.

Potholes—Explosives can be used to blast deep, wide craters (wildlife potholes), but this requires boring many holes and additional work (Figures 10.4a to 10.4d). To develop a wildlife pothole 18 feet deep, dig each hole at least 6 feet deep. Place 50-pound bags of ANFO into each hole. Holes should be about 10 feet apart.

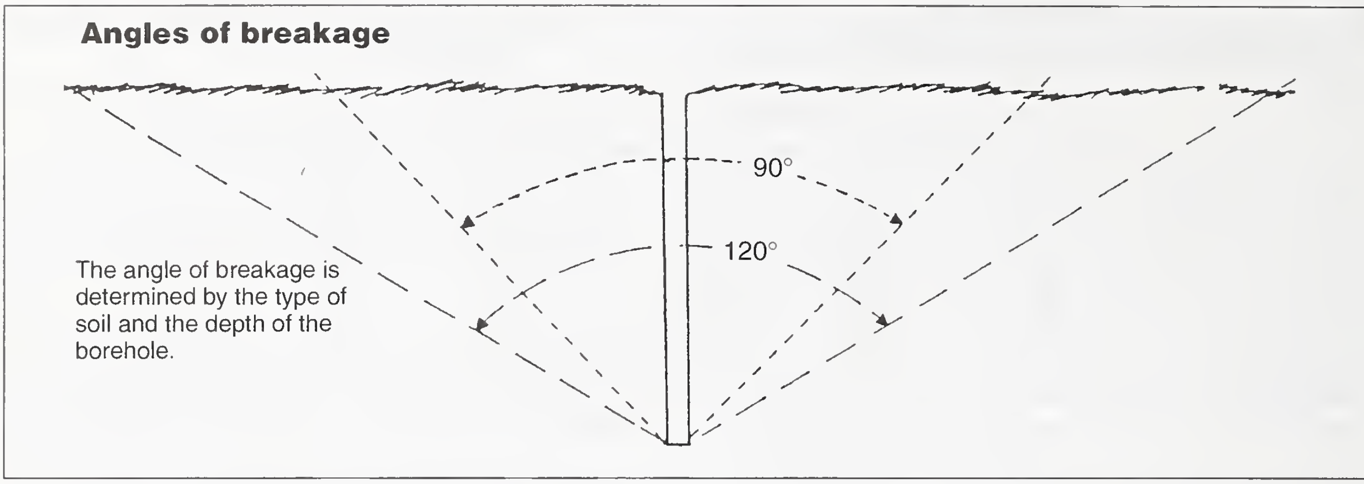


Figure 10.3—Angles of breakage determine hole width.

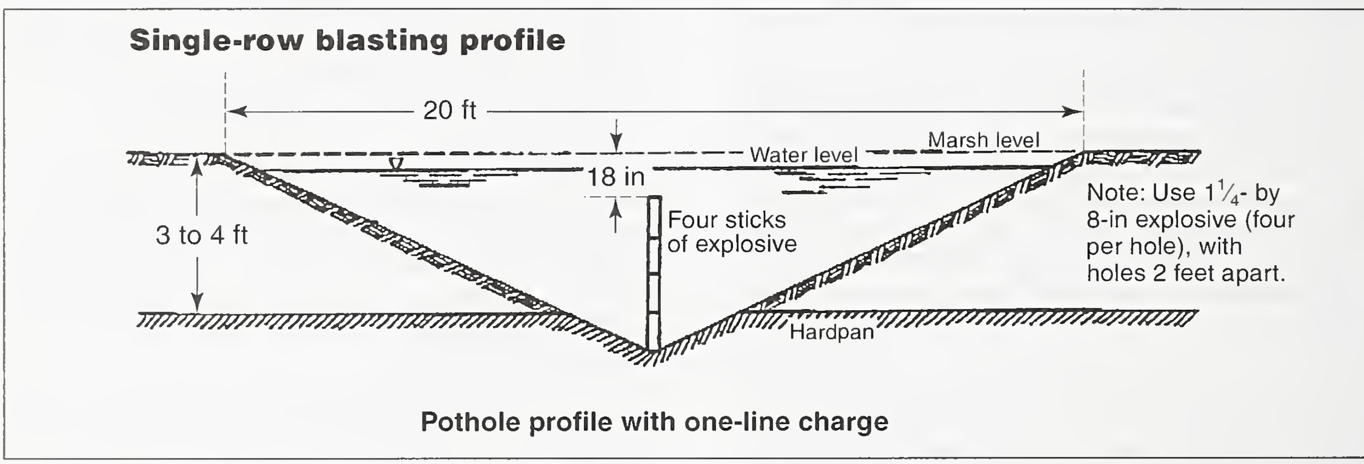


Figure 10.4a—Single-row profile for blasting potholes.

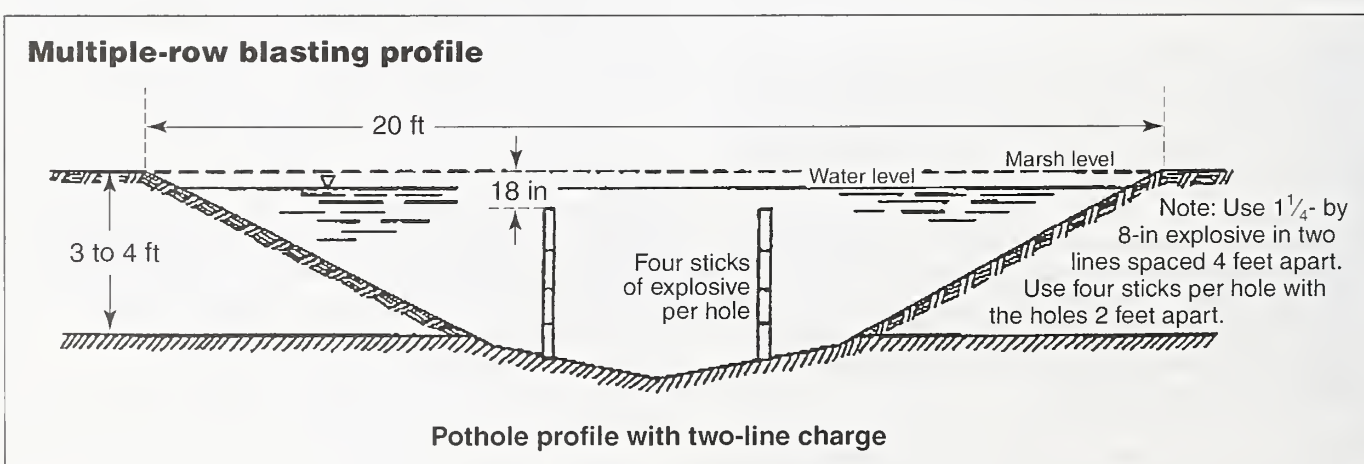


Figure 10.4b—Multiple-row profile for blasting potholes.

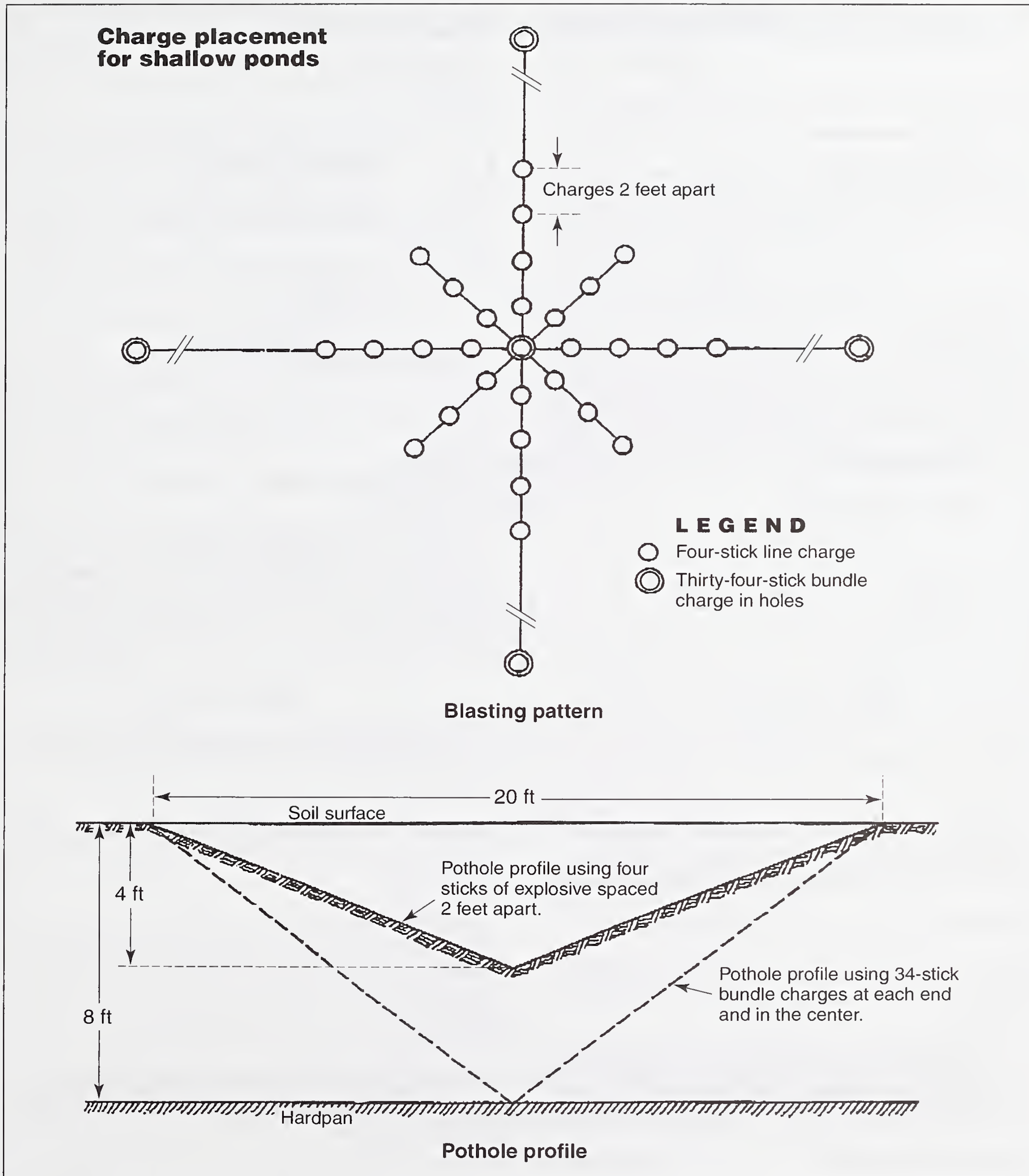


Figure 10.4c—Recommended charge placement for shallow ponds using 6-inch holes positioned along a crisscross pattern.

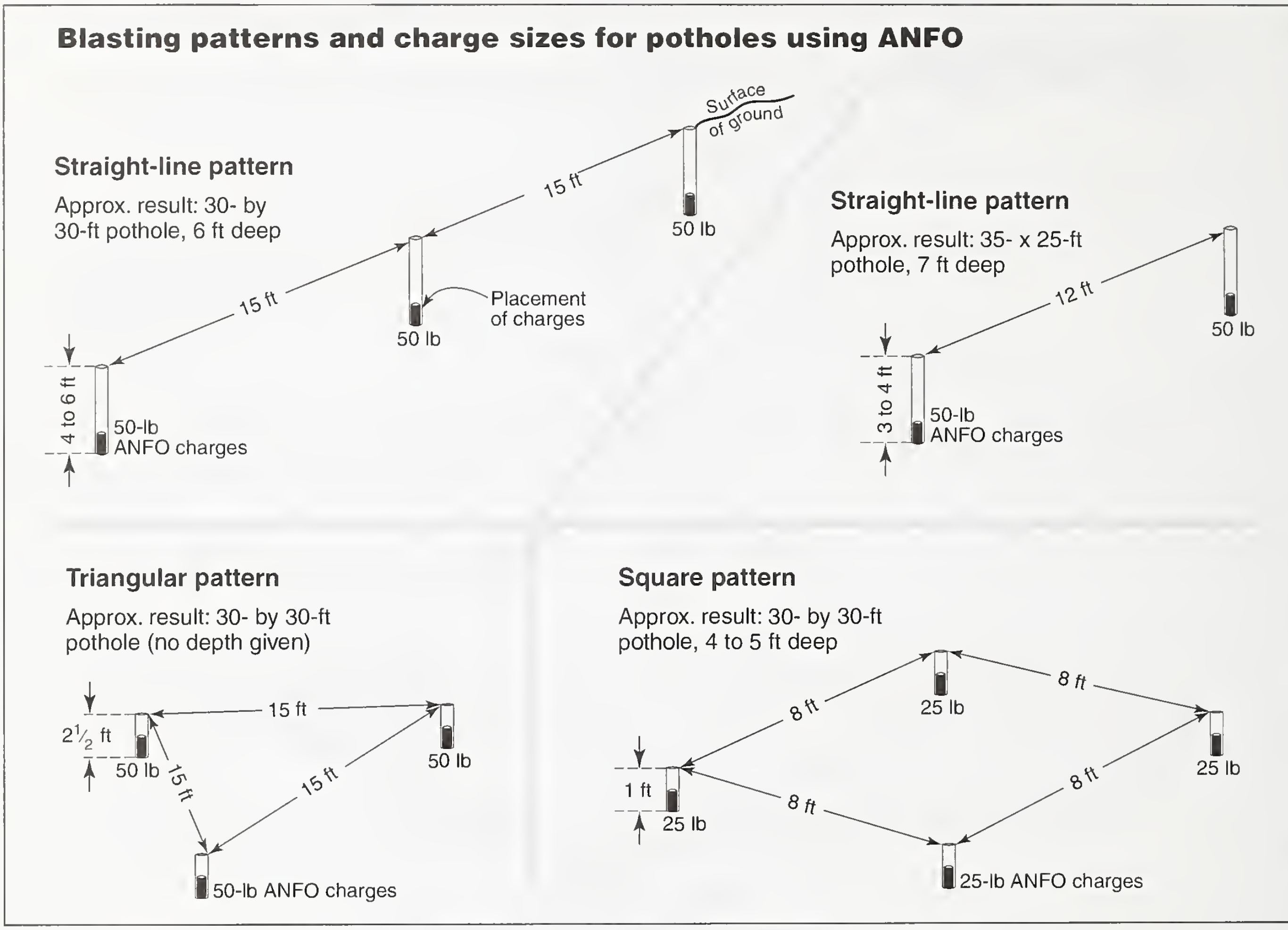


Figure 10.4d—Examples of blast patterns and charge sizes used to create potholes using ANFO.

Procedure—The step-by-step procedure for blasting ditches and potholes should be followed whenever possible. In some cases the procedure will have to be changed slightly.

1—Determine the depth and width of the ditch required.

2—Draw a cross section of charge depth and the angle of craters for two or more holes. Determine spacing between the holes.

3—Determine the type of soil, and position of obstructions, if any. Decide whether sympathetic detonation or charge-for-charge initiation is required.

4—Select the explosives.

5—Lay out the centerline of the ditch with stakes, mason line, string, or other material that will provide a guide for the line of holes.

In wet soil, punch holes in the soil with a driving bar or pointed wooden dowel, ensuring that all holes are the same depth. Put a piece of tape on the driving bar at the desired depth. If the soil tends to cave in, swing the dowel or bar in a circular motion to help pack the soil against the sides of the hole.

A small sledge may be needed to drive the bar in wet or damp soil. A posthole digger or shovel may be needed to dig holes in dry soil.

6—Place charges into the holes as they are dug. Stack the sticks of explosive one on top of the other, ensuring that each stick is in intimate contact with the stick below, until the column is about 8 to 12 inches from the surface.

7—Prime the first charge, or additional charges as required, with electric blasting caps or detonating cord.

8—Connect the detonators in a series circuit, or tie each pigtail into the mainline, which has been previously laid out.

9—Prime the det cord with a blasting cap (if applicable).

10—Connect cap leg wires into the mainline.

11—Follow standard safety and warning procedures and proceed with the blast.

12—Wait for all debris to settle.

13—Check the entire ditch for unexploded charges.

Ditch, pond, or pothole blasting will throw debris a great distance and well into the air. It may take some seconds for everything to settle. ***Stay under cover or far enough away to ensure that no debris will strike equipment or people. It is not uncommon for the Blaster-in-Charge to be ¼ mile away from a site where a large pond is being blasted.***

10.2 Beaver Dams

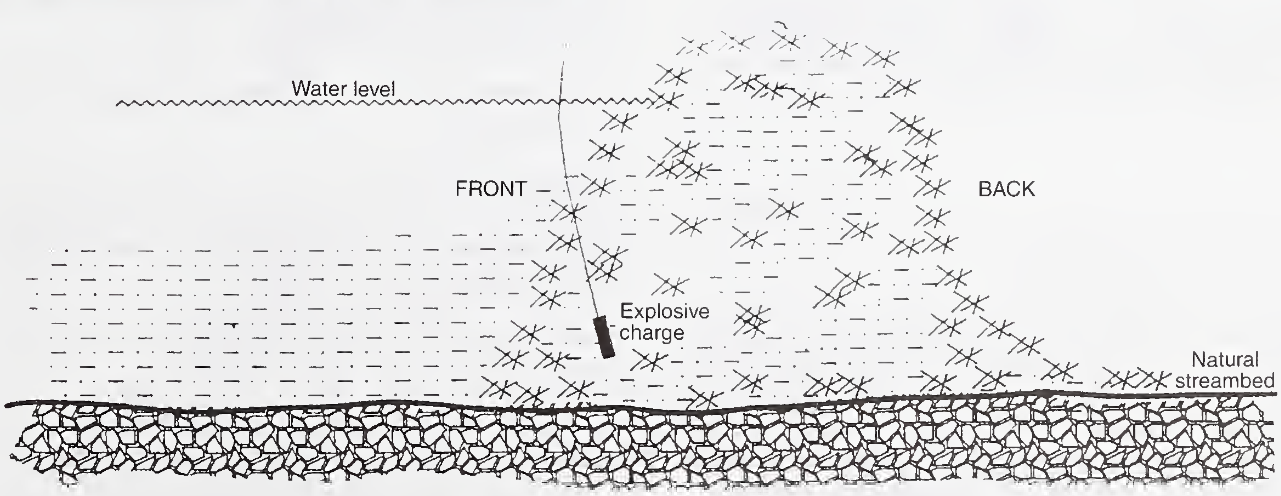
10.2.1 General

Breaching beaver dams with explosives is easy, quick, and doesn't require elaborate equipment.

Explosives can create channels from a few feet to several yards wide. The depth of the channel may be controlled to some extent by the amount of charge and the depth at which the charge is placed within the beaver dam.

A single line of charges placed along the front (upstream side) of the beaver dam is the simplest design. Charges are placed in the mud or silt about 10 to 15 feet apart and 8 to 12 inches above the gravel bed or natural streambed (Figure 10.5). The amount of charge or the number of cartridges in each hole will depend on the characteristics of the dam (mud or silt) and the width and depth of the breach required. This is largely a matter for experimentation at a particular site.

Placing explosives in beaver dams



Beaver dam cross-section detail

Figure 10.5—Locating explosives to remove beaver dams *(continued on next page)*.

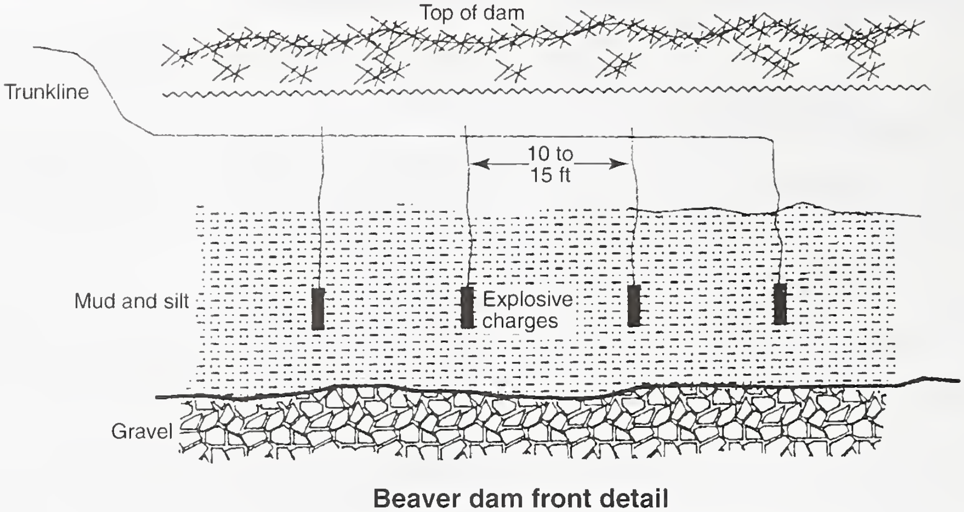


Figure 10.5—Continued.

10.2.2 Preparation of Charges

As a guide, charges are placed vertically as shown in Figure 10.5. They may be slightly inclined. In general, the holes for the charges should be made using a digging bar, or if available, a 2- to 3-inch by 6-foot-long dry aspen branch. Charges can be inserted into the oversize holes that were punched into the combination of mud and sticks in the dam.

To begin with, use about 1 pound of explosives for each charge. Increase or decrease the amount of explosives based on the results. If a lot of sticks and branches were used in the dam, more explosives may be needed.

10.3 Tree Stumps

Removing tree stumps with explosives is very difficult and dangerous, primarily because of the unpredictable reaction of the stump and the surrounding soil and rock. Root and soil structure, coupled with the strength and condition of the wood (green to rotten), all affect the results. Rocks hidden in the soil can be ejected many feet in any direction. Rely on someone with experience and knowledge in this field, especially when moving into a new area where root and soil structure are unknown.

The type of soil around the stump will have an effect on how well the selected explosive does the job. Nearly all soil will fall into one of the following categories:

- Damp but firm
- Dry and firm
- Wet and soggy
- Dry and soft.

Damp but firm soil is best for removing stumps. This allows the soil to be tamped (compacted) making a firm base so the explosive can build pressure, providing more upward force to remove the stump.

Dry and firm soil can be a good base, but may not tamp back into place.

Wet and soggy soil will not contain the blast pressure and will blast downward, as well as upward. More explosives will be required, which means more noise, more throw, less control, and a large crater.

Dry and soft soils, such as sand or loam, do not provide a good base to build pressure.

The type of wood, condition and height of the stump, and type of root system affect the procedures for removal.

Hardwood will respond to blasting better than softwood. Softwood tends to absorb explosive energy and does not break as readily when shocked.

Condition and Height of the Stump—The age of a stump, the time since it was cut, and the general soil and weather conditions in an area will determine whether a stump is solid. Old growth cut years ago will be rotten or beginning to rot. Freshly cut stumps will not have begun to decompose. Cedar stumps, even when newly cut, tend to have softer centers. Pine and fir will be relatively consistent throughout. Most of the hardwoods (oak, maple, walnut, alder) will not rot through the center, even after long exposure to the elements.

Softwood stumps, or those that are rotten, present a serious problem. A charge placed under the center of a decomposed stump will probably blow out the center of the stump. Roots left in the ground will have to be removed individually.

Most stumps are cut 2 to 4 feet above ground level, leaving sufficient wood to blast against without a blowout. Stumps cut higher will require more explosives or the stump will need to be shortened.

Type of Root System—Root systems will fall into one of the following categories:

* Taproots shallow
* Taproots deep
* Lateral roots shallow
* Lateral roots deep
* Lateral roots deep or shallow and uneven
* Lateral roots deep or shallow and evenly spread.

Often the type of root system is difficult to determine. The surrounding ground can give some clues to the type of root system that will be encountered. Figure 10.6 shows various root systems and configurations for loading explosives.

The wetter the ground throughout the year, the shallower the roots will be. If the soil is cohesive (sticks together), it will hold water and the roots will be shallow. If the soil is less cohesive (sandy or rocky), the roots will have to go deeper to find water.

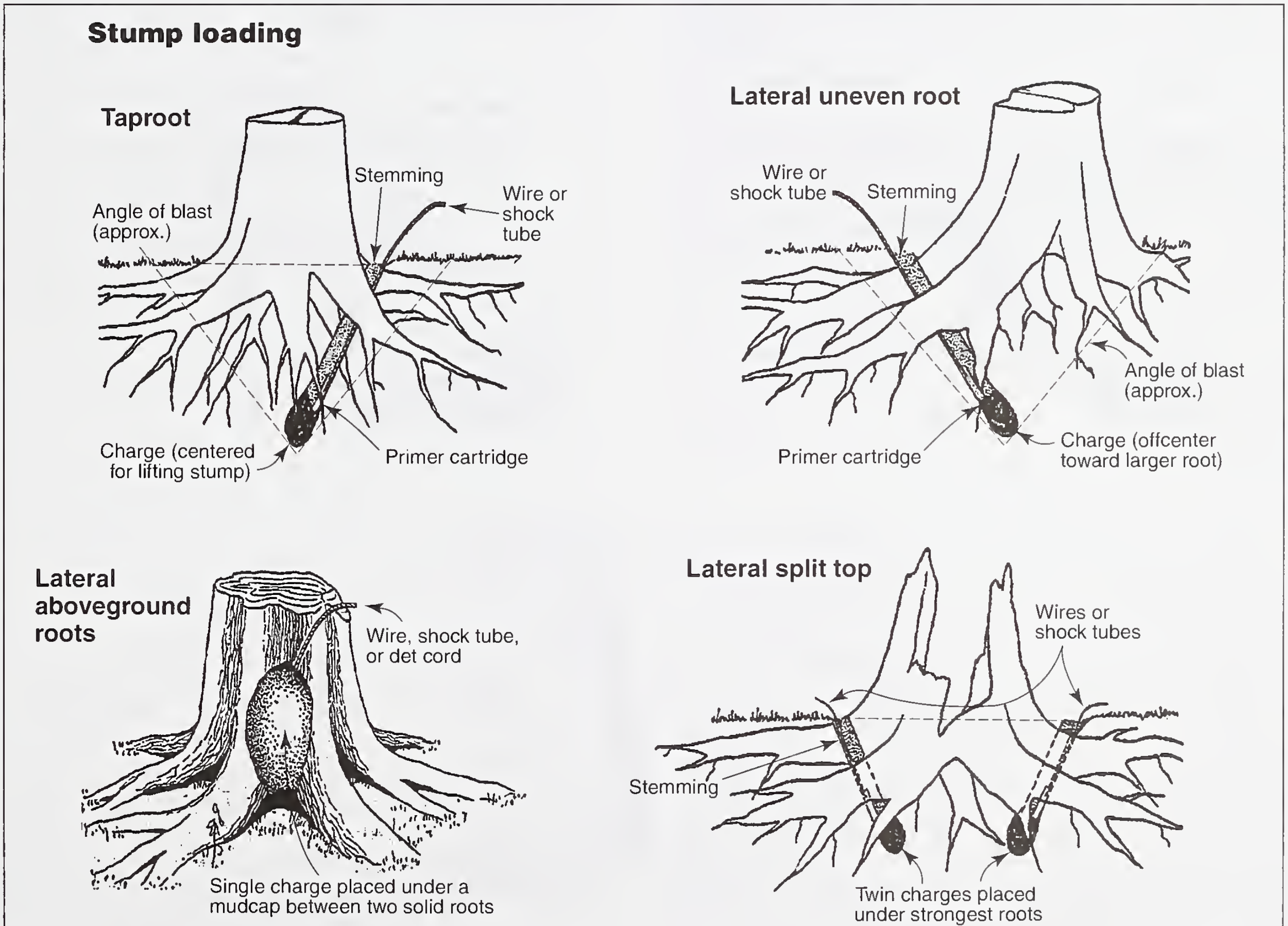


Figure 10.6—Examples of stump loading *(continued on next page).*

Stump loading *(continued)*

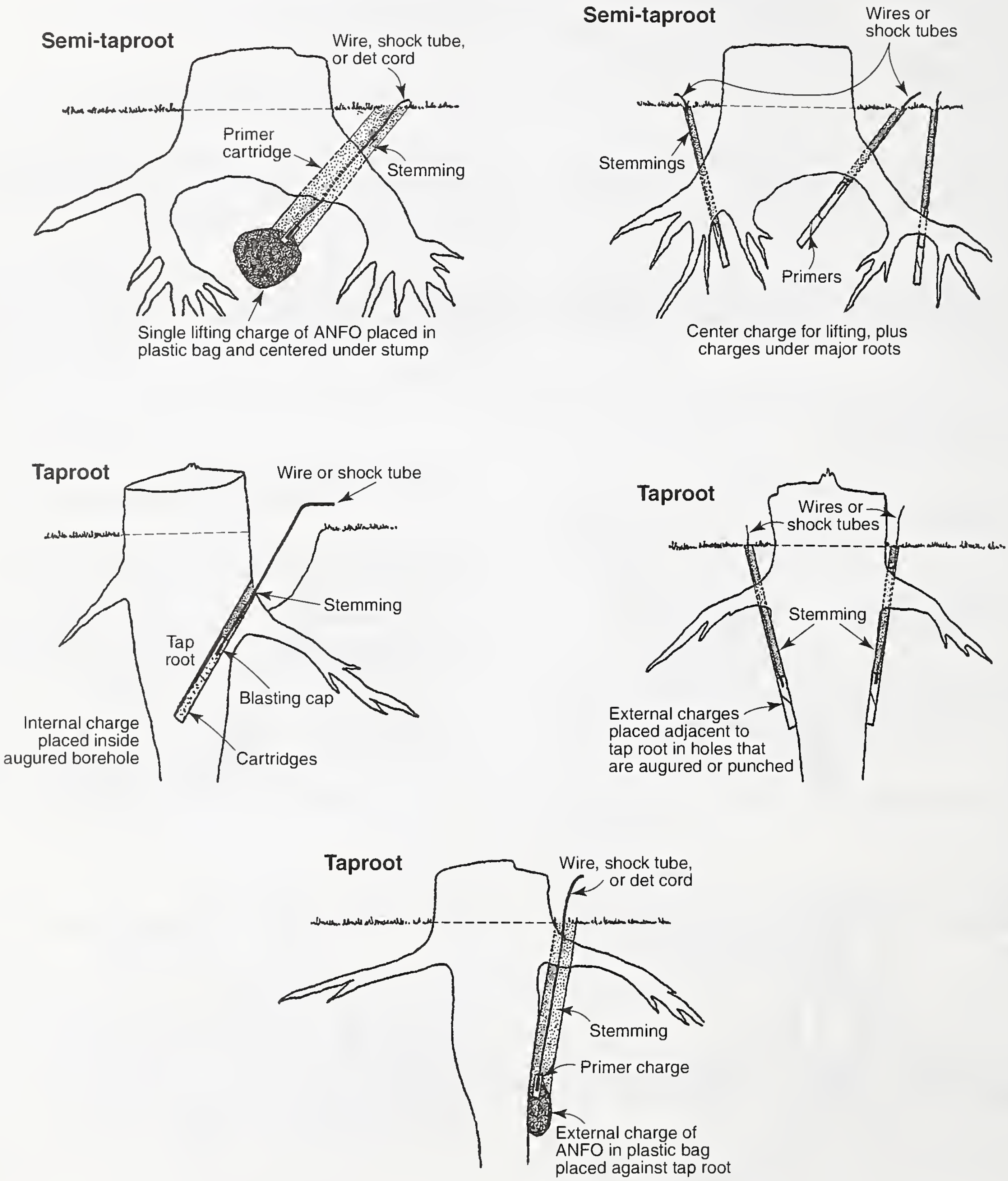


Figure 10.6—Continued.

If the ground is good, firm soil with no rock immediately apparent and the ground is fairly level or at least not on a hillside, the roots will probably be fairly deep. Whether there is a taproot will depend on the tree species. If the ground is fairly wet and does not completely dry out during the year, the root system will probably be shallow and spread out. Individual roots will not be very large. If the ground is dry and remains dry throughout the year, the root system will be deep and will not be widespread.

If the overburden (surrounding soil) is shallow with solid rock underneath, the roots will be shallow and spread out. If the rock has open planes of separation, roots may feed their way into the separations to obtain water.

Stumps found on hillsides will usually have uneven root systems. The majority of the roots will head downhill.

Stumps found near watercourses will usually have a root system that is denser and thicker on the side toward water.

Preparation for Stump Blasting

1—Determine the type of soil.

2—Determine, if possible, the type of root system.

3—Measure the diameter of the stump at the base.

4—Determine if the stump is to be lifted out, or just cracked and split.

5—Determine if the stump will have to be backfilled with soil before blasting.

6—Cut away vines, twigs, and sprouts.

7—Find a crotch at the base of the stump that points away from the area where the blaster will be stationed. If no crotch is visible, start digging until you find one.

8—Use appropriate equipment (driving bar, hammer, and shovels) to dig a hole under the stump. The hole will need to be large enough to accept the explosive charge and should extend beyond the middle of the stump.

Determining Charge Size—Lifting charges equal 3 pounds of explosives per diameter foot of stump for deep roots and 2 pounds per diameter foot for shallow roots.

If the core of the stump is rotten or if less than 2 feet of the stump is aboveground, two charge holes will be needed. These holes will be alongside the stump rather than under the middle of the stump. Each hole will take half of the designated charge.

A splitting charge equals 1 to 1½ pounds of explosive per foot of stump diameter (about half the lifting charge). Table 10.1 is a guideline for explosives selection for the different species of trees under different conditions.

Table 10.1—These tables can help you determine the amount of explosives needed for several species of trees under certain conditions.

NOTE: No absolute rule applies when computing the size of charge needed to blast various stumps. The figures given in the charts below are estimates which can be used for trial shots. The blaster must adjust charges up or down according to actual conditions experienced. More explosives are required for dry soil than wet soil. Large green stumps are more easily shot with distributed charges.

PACIFIC NORTHWEST
Douglas Fir Stumps *
(moist firm soil, external charge) **

Diameter 4 Feet Above Ground	Age Of Stump	Explosive (Cartridges) (1 1/4"x 8")
12'	Green Cut 1-5 yrs. Cut 5-15 yrs.	8 4 3
18"	Green Cut 1-5 yrs. Cut 5-15 yrs.	12 9 8
24"	Green Cut 1-5 yrs. Cut 5-15 yrs.	16 14.5 12
30"	Green Cut 1-5 yrs. Cut 5-15 yrs.	20 16 14.5
36"	Green Cut 1-5 yrs. Cut 5-15 yrs.	28 24 20
48"	Green Cut 1-5 yrs. Cut 5-15 yrs.	40 36 32
60"	Green Cut 1-5 yrs. Cut 5-15 yrs.	48 40 36
72"	Green Cut 1-5 yrs. Cut 5-15 yrs.	60 48 40

LATERAL ROOT
SOLID WHITE PINE
(moist soil, external charge) **

Diameter 1 Foot Above Ground	Kind Of Soil	Explosive (Cartridges) (1 1/4"x 8")
18'	Heavy Light	2-3 3-4
24'	Heavy Light	3-4 4-6
30"	Heavy Light	5-6 6-10
36"	Heavy Light	7-8 10-15
42"	Heavy Light	10-12 15-up

HARD WOOD STUMPS
(moist firm soil, external charge) **

Diameter 1 Foot Above Ground	Condition Of Stump	Explosive (Cartridges) (1 1/4"x 8")
6"	Green Dead	2 1
12"	Green Dead	4 2
18"	Green Dead	7 3
24"	Green Dead	10 4
30"	Green Dead	13 5
36"	Green Dead	14 up 6 up

TAP-ROOTED
YELLOW PINE OR HICKORY
(External Charge) **

Diameter 1 Foot Above Ground	Condition Of Stump	Explosive (Cartridges) (1 1/4"x 8")
6"	Green Dead	2 1
12"	Green Dead	3 1 1/2
18"	Green Dead	5 2
24"	Green Dead	7 3
30"	Green Dead	11 3 1/2
36"	Green Dead	14 5

* For Cedar and Hemlock, load same as Fir. For Spruce, about 75% of above. Alder and Maple, about 50% of above.

**For internal charges placed inside of augered bore-holes in roots, reduce the above loading figures by 50%.

Loading amounts given in the above charts are for lifting the stump. For splitting stumps for later removal by tractor, reduce charges by 50%.

10.4 Hazard Trees

10.4.1 Hazard-Tree Felling With Explosives

Felling hazard trees with explosives is often safer than felling them with a power saw because personnel are farther from the tree when the danger is greatest. General Blasters and fireline explosives Blasters can be certified by Forest Service Blaster Examiners for hazard-tree blasting. All hazard trees must be assessed before they are felled. Extreme care is needed when trees have significant lean, are rotten, weak, or on fire. Always approach a hazard tree away from the lean. When assessing a hazard tree, answer the following questions:

Q: ***Is the tree green, dead, hollow, or rotten?*** Explosives must be spread across the face of a dead, hollow tree to avoid blowing a hole in its center and leaving the tree standing. A live, solid, green tree may require slightly more explosive concentrated in one location and shaped in a pyramid to develop an appropriate shock wave. Look for conks, broken tops, basal scars, cat faces, or numerous downed limbs that may indicate internal rot. If many trees are down in an area, the trees may have root rot.

Q: ***Is the tree burning?*** If the top of the tree is burning, use only watergel, emulsion, or PETN-based explosives or explosives approved for fireline construction (FLE). If the tree may fall across burn control lines, special precautions may need to be taken. If the tree is burning at its base, ***Stop! Do not use explosives; they might catch fire. Explosives that are on fire must not be touched. Do not attempt to extinguish explosives that are on fire.***

Q: ***What is the tree's diameter where the explosives will be placed?*** Measure the diameter of the tree at chest height or wherever the explosives will be placed.

Q: ***Should external or internal blasting methods be used?*** External charges will create substantially more air blast. Internal blasting requires drilling a hole in the tree for the explosives charge (Figure 10.7). This method is not recommended for hollow or rotten trees, or trees that are so hazardous that drilling might trigger the tree's fall.

With external blasting, the explosives will be placed on the outside of the tree in one location (Figure 10.8) or the tree will be wrapped with fireline explosives (Figure 10.9). Wrapping is the least-preferred method of hazard tree blasting because the direction of fall is left to chance. A single wrap of explosives around a large tree will leave the tree standing, but weakened—not a desirable outcome.

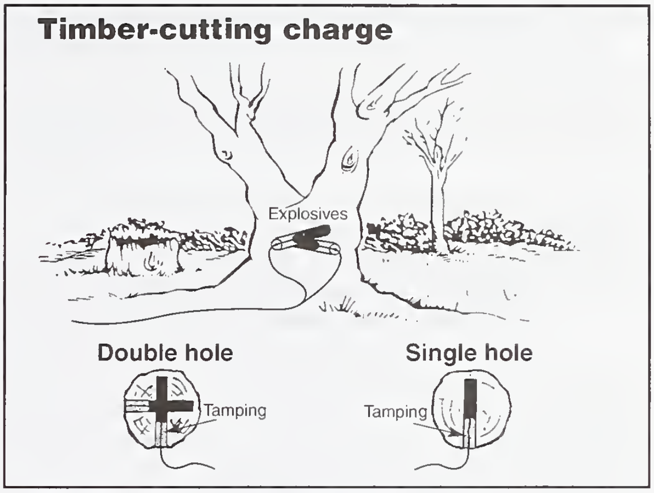


Figure 10.7—Internal timber-cutting charge.

Figure 10.8—External timber-cutting charge.

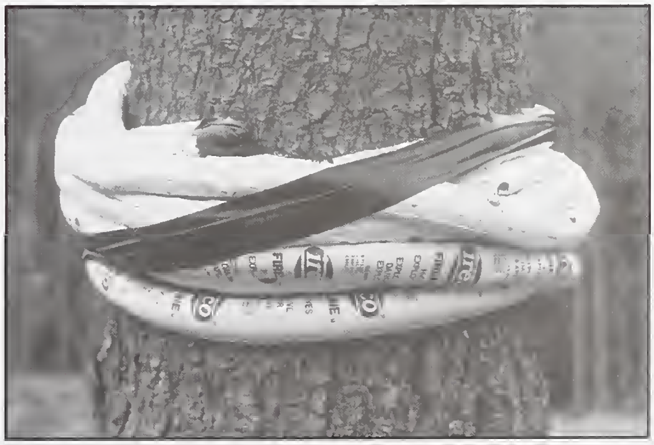


Figure 10.9—Tree wrapped with fireline explosives.

Internal Hazard-Tree Felling—Internal hazard-tree felling is often preferred because fewer explosives are needed and the shock wave and noise are reduced. However, the direction of fall is left to chance and the tree has to be disturbed to drill a hole for the explosives.

The formula to be used for internal hazard-tree felling with explosives is:

$W = D^2/250$ (Metric equivalent: $W = D^2/3560$)

where: W = Weight of the explosives in pounds (kilograms)

D = Diameter of the tree in inches (centimeters), where the explosives will be placed.

Example:

Tree diameter = 24 inches (61 cm)

$W = (24)^2/250 = 576/250 = 2.3$ pounds

(Metric equivalent: $(61)^2/3560 = 3721/3560 = 1.04$ kg).

In this example, if your explosives are supplied in 1-pound sticks, use three sticks (always round up). If your explosives are supplied in 0.5-kg sticks, use two sticks. If you use packaged emulsions or watergels that can be extruded into the borehole, use 2.3 pounds (1 kg) of explosives.

If you use a 1¼-inch linear watergel explosive (fireline explosive), divide 2.3 pounds by 0.6 pounds of explosive per foot to get 3.83 feet (1.17 m) of explosive. Rounding up, use 4 feet (1.2 m) of linear fireline explosives.

Once the hazard tree has been loaded with explosives, the procedures for detonation are the same as for fireline explosives. Use EBW's and the customary 500 feet (152 m) of electric lead line to get the required distance from the blast, and place appropriate guards.

External Hazard-Tree Felling—External hazard-tree felling is preferred when the Blaster needs a high degree of control over the direction the tree will fall. Airblast will be higher for this method than with internal blasting. It is often difficult to place large amounts of bulk explosives in one location on a tree. Packaged explosives are an exception. They can be removed or extruded from the package, shaped, and stuck to the tree (Figure 10.10).

The formula to be used for external hazard tree blasting is:

$W = D^2/40$ (metric equivalent: $W = D^2/569$)

where: W = Weight of explosives in pounds (kilograms)

D = Diameter of the tree in inches (centimeters), where the explosives will be placed.

Example: The diameter of the tree is 24 inches (61 cm).

Then: $W = (24)^2/40 = 576/40 = 14.4$ pounds (Metric equivalent: $(61)^2/569 = 6.54$ kg).

Figure 10.10—External packaged explosives in a shaped form can be attached to a tree.

If you use explosives supplied in 1-pound sticks, use 15 sticks in one location (always round up). If you use explosives supplied in 0.5-kg sticks, use 13 sticks. If you use explosives that can be extruded from the package, use 14.4 pounds (6.54 kg) of explosives.

If you use 1¼-inch linear watergel fireline explosives (FLE) that weigh 0.6 pounds per foot, use 14.4/0.6 = 24 feet (7.3 m) of linear fireline explosives in one location (Figure 10.11).

Table 10.2 gives the explosives loads for specified tree diameters.

Figure 10.11—External fireline explosive charge coiled on the side of a tree.

Hollow Trees—Hollow trees can be felled by wrapping linear (fireline) explosives around the outside of the tree, using one wrap of explosive per inch of holding wood.

Special Considerations

✱ Place the detonator or detonating cord on the top of the pyramid of explosives to develop shock waves to fell the tree.

✱ When the tree's bark is unusually thick or loose, it should be removed before placing the explosives (this may not be safe on some trees).

✱ Always place explosives on the side of the tree toward the direction of fall unless this would be too dangerous.

✱ Never assume that a tree will fall in a given direction.

✱ Assume that all blasts will produce flying debris.

✱ Always blast from a position at least 500 feet (152 m) from the tree.

✱ Always use a detonation system that is not susceptible to electromagnetic radiation (EBW's or a nonelelectric detonator).

✱ Use extreme care around hollow, rotten trees. Spread explosives across the face of the tree to avoid blowing a hole through the center. That could leave the tree standing and make it even more dangerous to approach.

✱ When in doubt, use more explosives than the formulas indicate, especially when wrapping large trees with linear fireline explosives.

✱ Always follow the rules and practices given in this guide and on the instruction sheet in every box of explosives.

✱ Take special precautions when burning trees may fall across burn control lines.

10.4.2 Tree Topping With Explosives

Biologists sometimes prefer having trees topped with explosives rather than cut off when creating nest trees. The jagged surface left after blasting accommodates birds of prey when they build nests. It is generally more desirable to climb the tree and place the explosives than it is to hoist explosives into place. When explosives are hoisted into a tree, more pounds of explosives are needed to top the tree than if the explosives are placed by hand. Only certified Blasters and climbers may place explosives in a tree.

Table 10.2—Tree diameters and explosive loads needed.

Tree diameter (D) inches	Tree circumfrence (πD) inches	Internal load ($D^2/250$) lb	External load ($D^2/40$) lb	External load (1-lb sticks)	External feet of FLE in one location	Wraps of FLE	Feet of wrapped FLE
8	25.0	0.27	1.6	2	3	2	4
12	37.7	0.60	3.6	4	6	3	9.5
16	50.3	1.07	6.4	7	11	4	17
20	62.8	1.67	10.0	10	17	5	26
24	75.3	2.40	14.0	15	24	6	38
28	88.0	3.26	19.6	20	33	*7	52
32	100.5	4.27	25.6	26	43	*8	67
36	113.1	5.40	32.4	33	54	*9	85
40	125.6	6.67	40.0	40	67	*10	104
44	138.2	8.07	48.4	49	81	*11	127
48	150.8	9.60	57.6	58	96	*12	151

*Not recommended

Guidelines for the amount of explosives needed to top a tree of a given diameter can be found in Section 10.4.1. If an explosive charge is placed on the outside surface of the tree, more explosive will be needed than if a hole is drilled and the charge is placed inside the tree. Use watergel or emulsion-type explosives for tree topping. ***Do not use sensitive nitroglycerin-based explosives for this activity.*** The pounds of explosives needed to top a tree equal the diameter of the tree (in inches) squared, divided by 40 for external charges or divided by 250 for internal charges.

If the tree has a thick layer of bark or an irregular surface and external charges are used, the Blaster may opt to use a few more pounds of explosive than indicated by the formula. It may be best to remove thick layers of bark before placing the explosives. Explosives should be packaged and placed to maximize the direct contact surface area between the charge and the tree. Charges should be bundled or shaped in the form of a cone or pyramid. A detonator or detonating cord should be placed at the top of the cone pointed in the direction of the desired blast. When using an internal charge, be sure to drill the hole so explosives can be located at the center of the tree's mass at that point.

Electric detonators must not be used for tree topping. Nonelectric blasting caps, EBW's, or detonating cord may be used as initiating systems. Detonating cord can be spiraled down the tree trunk to leave a mark that simulates a lightning strike. During dry conditions, detonating cord may start a fire in nearby brush or other fuels. As with all blasting operations, a minimum specified distance must be established to ensure personnel are safe from flying debris. When fireline explosives are used, the minimum distance is usually 500 feet. In the case of tree topping, the minimum distance should also take into account the possibility that the treetop might fall into a snag or topple other trees. The Blaster must select appropriate safety zones for all personnel.

10.5 Avalanche Blasting

10.5.1 General

Explosives are used in avalanche control to test slopes, release avalanches, and stabilize snow.

Avalanche Blasters must follow State and local laws where applicable.The standard charge is capable of developing a detonation pressure equal to 1 kg of TNT. Several types of explosives can develop the appropriate detonation pressure. You can calculate the detonation pressure of an explosive if you know its detonation velocity and density (Chapter 2—Explosives).

10.5.2 Initiating Devices

Avalanche blasting is based on nonelectric detonating systems or systems that are not susceptible to initiation from the high levels of static electricity prevalent during snowstorms and near ridgecrests. Even with nonelectric blasting caps, avalanche blasting should not be done when there is evidence of strong static electricity (cumulonimbus clouds, electric buzzing).

Cap and Fuse—Information concerning the use of cap and fuse for avalanche work has been deleted. The Forest Service has discontinued the use of cap and fuse in blasting operations.

Nonelectric Detonating Systems—Nonelectric systems consist of a thin plastic shock tube that has a light dusting of reactive powder on its inside surface (about 1 pound of powder for 70,000 feet of tube). When initiated, this tube will reliably transmit a low-energy signal from one point to another by means of a shock wave, much like a dust explosion. The tube will reliably detonate around sharp bends and through kinks. Because the detonation is sustained by such a small quantity of reactive material, the outer surface of the tube remains intact while the shock is being transmitted. A nonelelectric system can be initiated by det cord or by a blasting cap. It will reliably initiate instantaneous or delay nonelectric blasting caps. Nonelectric systems are ideally suited for precision, nonelectric delay initiation (Chapter 3).

Exploding Bridgewire—EBW detonators do not contain any primary explosive. They are not detonated by stray currents, static electricity, radio transmission, or fire. A large, precisely timed electrical pulse from a special firing set is required to detonate an EBW. This firing set delivers the electrical charge to the detonator through up to 2,500 feet of hookup wire. Three detonators, the RP-80, the RP-83, and the RP-501 may be used with this system (Chapter 3).

10.5.3 Explosive Assemblies

Cast Primers—Cast primers are usually high-density cast or pressed cylinders of TNT, Pentolite, or other ingredients. TNT is a fast, powerful explosive that is relatively insensitive to accidental detonation by shock. It was developed by the military to withstand the rigors of the battlefield. Its fumes do not produce headaches, as do other explosives. The fumes are toxic, but this is not a problem in normal outdoor use. One of TNT's disadvantages is that it leaves a messy black crater—another is its high cost. A No. 6 blasting cap will not reliably detonate pure TNT while a No. 8 cap will. Cast primers of TNT include more sensitive explosives, such as PETN.

Gelatin Primers—Gelatin primers are less expensive than cast primers and do not leave a black crater. They detonate as fast as TNT, but are slightly more bulky. They have a high percentage of nitroglycerin; they cause headaches, they deteriorate, and they are more sensitive to shock than primers that consist of TNT. Nitroglycerin begins to freeze at -29 °C (-20 °F). It is susceptible to premature detonation when a hole is made using a powder punch. Therefore, it should not be used when temperatures reach -20 °F (-29 °C).

Two-Component Explosives—Gelatin and cast primers are classified as high explosives and must be stored and handled according to strict codes. Because of regulations dealing with explosives security, storage is expensive. Where there is a limited need for explosives, avalanche workers may wish to avoid the more expensive storage requirements by using a two-component system. Stored separately, the components are not high explosives. They are only classified as high explosives when mixed. The advantages for storage are offset by the higher cost of materials, lower detonation speeds, bulkier charges, the inconvenience of mixing the explosive in the field, and the requirement of a ½-hour mixing time to bring the mixture to full strength. Mixing should be done at temperatures of 32 °F (0 °C) or above. Once mixed, the explosives will detonate at -50 °C (-58 °F) or lower.

General Considerations—As soon as a detonator is inserted into the explosive, the system is armed. From this instant, the relatively insensitive explosive containing a sensitive cap is vulnerable to accidental detonation. Delay arming as long as possible. Usually it is possible to arm the explosive just before placing the charge on a slope.

Arming Cast Primers—Figure 10.12 shows the steps for arming cast primers with nonelectric detonators. Most cast primers are manufactured with a hole through the middle, and an offcenter hole that does not go all the way through the primer. The central hole is designed to be detonated by high-explosive detonating cord. The offcenter hole is usually lined with a primer that is sensitive to a No. 6 blasting cap. The cap must be placed in the proper hole to avoid a misfire. In avalanche work, it is convenient to lace the nonelectric shock tube tightly through the central hole and into the offcenter hole, snug against the bottom of the hole. The assembly is then taped securely.

Arming Gelatin Primers—Figure 10.12 shows a gelatin primer being armed. Gelatin primers have no precast holes. Two diagonal holes must be punched before arming the primer. First, punch a hole through the charge with the punch end of the crimper, then rotate the charge one-fourth turn and punch a second hole slightly deeper than the length of the cap. The shock tube is laced through the first hole and the cap is inserted into the second hole. The assembly is taped securely.

Arming primers with nonelectric detonators

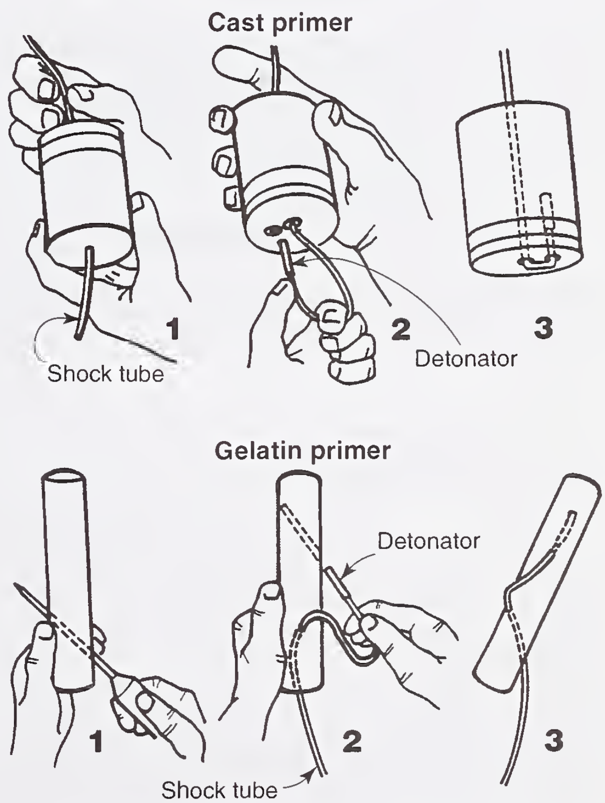


Figure 10.12—Arming cast and gelatin primers with nonelectric detonators.

Arming With Detonating Cord—Explosives may be initiated with det cord. Taping a detonator to the detonating cord or joining the cap and the cord with special connectors arms charges. The explosive end of the cap should point along the detonating cord toward the main charge. At least 25-grain-per-foot cord shall be used. Consult the manufacturer for the proper size of cord. Because the cap is exposed and vulnerable to accidental shock, don't make the final connection of cap and detonating cord until you are at the blasting position and ready to fire.

10.5.4 Using Hand Charges With Nonelectric Detonating Systems

Prepared charges, including the detonators, are carried in the control team members' packs. Team members should not be loaded so heavily with charges that their skiing will be hampered. ***Detonators are carried separately from explosives***. Team members keep in constant contact using radios. Once at the blasting position:

1—Make sure all possible runout zones are free of people and traffic. When runout zones are not visible from the blasting point, arrange for signals from an observer.

2—Work with only one charge at a time.

3—Arm the charge with a nonelectric detonator.

4—Go to a safe position and commence the detonating sequence.

10.5.5 Cornice Control

Surface charges of cast or gelatin primers, or their equivalent (ANFO or slurries), can be placed along the estimated tension line of a cornice roof when blasting cornices for avalanche control. The recommended steps for cornice blasting with surface charges are:

1—Select the number of charges needed to cover the tension line of the cornice roof. Lace each charge with an 18-inch length of detonating cord, referred to as a branchline.

2—Set out a trunkline of detonating cord parallel to the safe working line.

3—Set the first charge into position along the working line. Attach the branchline of the first charge to the trunkline with a girth hitch, clove hitch, or other approved connection.

4—Connect adjacent charges until all are connected.

5—After connecting all branchlines to the trunkline, carefully push each charge from the safe working line to the presumed tension line of the cornice.

6—Align each branchline perpendicular to the trunkline.

7—Loop the end of the trunkline to form a continuous loop back to the starting point. Attach the line to complete a loop.

8—After the charges are in place, tape a nonelectric or EBW detonators to a 3-foot length of detonating cord. The explosive end of the cap must point down the trunkline toward the charges. Properly attach this assembly to the trunkline (using a pigtail) just before retreating to initiate the blast.

9—Commence with the normal detonating sequence for nonelectric or EBW detonators.

A more efficient blasting scheme is to bury the charges in a row of boreholes. In borehole cornice blasting, one may achieve satisfactory results with about half the explosives used in surface blasting. It is also possible to blast effectively with low-cost, low-detonation-pressure explosives. Although borehole blasting increases efficiency, boring holes along the cornice's presumed tension line exposes the Avalanche Blaster to significant danger. Safety in borehole blasting depends critically on a blasting crew's ability to judge the safe working line correctly and the feasibility of maintaining a tight, secure belay on persons drilling the holes.

The recommended steps in borehole blasting are:

1—Once the driller is belayed securely, the driller steps into position on the safe side of the safe working line and drills a row of holes no deeper than half the thickness of the roof. Boreholes should be drilled as close as possible to the cornice's potential tension line.

2—Boreholes should be sized to allow the charges to fit as tightly as possible. Space holes as needed. An auger might be needed to bore the holes because cornice snow is normally quite hard.

3—Once holes are bored, string out the trunkline of det cord. To prevent losing explosives, if the cornice suddenly collapses, secure a free end of the mainline to an anchor until the system is ready to be detonated.

4—Insert a charge attached to the branchline into the first hole. Connect the branchline to the trunkline. Fill the hole with snow and compact it lightly.

5—After preparing all boreholes, make a continuous loop of the trunkline and tie it to the main trunkline so all charges are inside the loop. Attach a blasting cap to a 3-foot length of detonating cord. The explosive end of the cap must point down the trunkline toward the first charge. Tie this pigtail to the trunkline just before retreating to initiate the blast. Check with the guards before firing.

6—Because detonating cord plays an important role in cornice blasting, become acquainted with the basic techniques for working with this high explosive (Section 3.4—Detonating Cord).

10.5.6 Explosives Safety

Avalanche blasting work, including storage, transportation, and handling of explosives, must comply with all laws.

General

* An avalanche should not be released artificially until the avalanche path, including the potential runout zone, is clear of people.

* If there is any chance that someone will enter the path during blasting, position the avalanche guards at the entrance to the avalanche path.

* During unstable conditions, artificially releasing one avalanche may trigger sympathetic releases over a wide area. Consider such possibilities and clear the appropriate area.

* Always handle explosives with utmost care.

Personnel

* Each avalanche-control team shall consist of a qualified, licensed Blaster and at least one trained assistant.

* All members of the blasting team should be in good physical and mental condition and should be competent ski mountaineers. They shall all be equipped with avalanche transceivers and other safety gear as required (probe, ski poles, and shovel).

* All members of the blasting team shall be properly trained and qualified.

* Responsibility for preparing and placing charges shall not be divided. The Blaster-in-Charge is responsible for supervising all phases of blasting.

* All members of the blasting team shall be able to communicate with each other at all times.

Explosives

* Explosives should have a shelf life in normal storage of at least one operating season.

* Explosives should not be packaged in metal containers.

* Explosives should have excellent weather resistance.

* Explosives shall not be sensitive to shock.

* Explosives shall be stored in an approved magazine.

Detonation Systems

* The detonation system should be as simple as possible. Recommended systems consist of explosive, EBW caps, and nonelectric detonating systems.

* Caps shall be protected fully from external shock.

Preparing the Detonating System

* To prevent misfires, the detonator assembly shall be properly attached to the explosive charge.

* Charges shall be armed with detonators as late as possible in the blasting sequence.

Placing the Charge from the Control Route

* Place the charge on the target and retreat to a safe position.

* In cases where the charge could slide down a hard snow surface, it must be belayed or anchored.

Retrieving Misfires

* A conscientious effort must be made to retrieve each misfire.

* If conditions make it impossible to retrieve the misfire, the slope should be closed and a search begun. The slope shall remain closed until a reasonable effort has been made to retrieve the misfire. If the misfire is not found, record its probable location. Record as much information in hopes that the charge can be retrieved later.

* The blasting team must wait at least 1 hour before approaching a misfire. Note: Some State regulations may require a longer wait. A misfire that is burning or smoking must be left alone.

* The normal procedure is to disarm and retrieve the charge before escaping to a location where the risk of avalanches is low.

* Deviation from the normal procedures (such as planting a second charge next to the misfire) depends on the cause of the misfire, the sensitivity of the explosive, and location.

10.5.7 Military Weapons

Certification for Use—All employees who use military weapons must be certified every 3 years by the National Avalanche Center (NAC). Certification is based on results of written and oral examinations and a practical field exercise.

In addition, applicants must meet these requirements of the Organized Crime Control Act of 1970:

* Be over 21 years old.

* Have never been indicted or convicted for any crime punishable by imprisonment for a term exceeding 1 year.

* Not use unlawful drugs.

* Not use alcohol to excess.

The written examination covers the safety of weapon use and the handling, transportation, and storage of ammunition.

In the oral examination, the applicant must demonstrate an overall understanding of safety rules for military weapons, firing techniques, and principles.

Applicants must demonstrate in a field exercise, or in a mock field exercise, the ability to handle ammunition and to set the ammunition for loading, aiming, and firing. They must demonstrate the actions to take in the event of a misfire, cook off (when the explosive burns), or a dud.

From the results of the written and oral examinations and the field exercise, NAC or a designee will determine if the candidate is fully qualified. Applicants who are not fully qualified, but have not been eliminated will be placed in an in-training category until they have obtained additional skills and experience. They will then be reexamined for certification. The only way to be placed in the "in-training" category is through the certification process.

Certificates must be renewed every 3 years. Renewal will be under the same conditions as the issuance of the original certificate. A yearly refresher course shall be given to all personnel who use military weapons.

Certificates can be suspended at any time by the Forest Supervisor, or upon the recommendation of NAC to the Forest Supervisor. Suspensions will be made when safety violations have occurred or when evidence exists that there is a lack of skill. To regain certification, a suspended employee must pass the exams and field exercise before being recertified by NAC.

Each Region shall have a Standard Operating Procedure (SOP). The National Avalanche Center or a designee shall approve this procedure.

Military Ammunition Storage—Facilities shall be fireproof, weatherproof, bulletproof, and theft-resistant. All aboveground storage must conform to the requirements for lightning protection found in the current edition of the National Fire Protection Association Standard No. 78.

Ammunition may be stored in approved magazines only in cordwood style—piled so the rounds touch each other in their original cardboard tube or other type of original packing cover. The minimum distance from the magazine to inhabited buildings, highways, ski lifts, and designated ski runs is 800 feet for 75-mm ammunition and 1,200 feet for 105-mm and 106-mm ammunition. These minimum distances provide reasonable protection from blast effects of an accidental detonation (Chapter 4—Storage).

Aboveground Storage—Magazines that store nothing but ammunition must meet the minimum requirements described in ATF Explosive Laws and Regulations (ATF p. 5400.7) dated 10/91 or the latest edition, Subpart K—Storage, Section 55.207, with the following exceptions:

* The interior of the magazine does not need to be constructed of a nonsparking material.

* Only outdoor facilities shall be used. All doors shall be constructed of $\frac{3}{8}$-inch steel plate and lined on the inside with 2 inches of hardwood.

Ammunition may be stored aboveground less than the minimum distances of 800 and 1,200 feet if the storage facilities are designated to resist mass detonation and to provide directional control of blast and fragments.

For magazines with 12-inch-thick reinforced concrete walls and roof, or with 3 feet of earth cover against the walls and with the access door in the roof, the following rules for ammunition storage apply:

Type of round	Minimum round separation (inches)	Fragment hazard distance (feet)
75-mm M-48 and M-309 HE	0[1]	40
75-mm M-349 HEP-T	3.00	40
105-mm M-323 HE	4.00	60
105-mm M-326 HEP-T	4.75	60
106-mm M-346 A1 HEP-T	5.00	60

[1] Winerack not required. All other ammunition must be in an approved winerack.

Minimum round separation may be provided by a "winerack" fabricated from concrete, concrete pipe, or tubing with sand as a separating medium. Materials other than these may be used for winerack construction, provided they have been approved by the Forest Service. Cardboard tubes shall be completely contained within the winerack except that the primer end may stick out about 1 inch to make it easier to remove the tube from the winerack.

Where magazine access doors are in the sidewalls, the minimum distance of 800 feet for 75-mm ammunition and 1,200 feet for 105- and 106-mm ammunition must be used as a fragment hazard distance in the direction the door faces. Barricades or other means can be used to reduce the fragmentation hazard distance and the minimum blast distance. Directional control of airblast and fragments can be achieved by designing a weak wall or roof (usually by placement of the access door) or by strengthening the walls with earth.

The fragmentation hazard distance and the potential damage from the airblast of an explosion must be considered when designing and locating an ammunition storage faciltiy.

The following thicknesses of cover or embankment are considered adequate to protect against fragment throw. These criteria should be used in areas where fragment throw cannot be permitted in certain directions.

Type of round	Earth cover (feet)	Hard rock or concrete (feet)
75-mm M-48 and M-309 HE[1]	3.99	3.38
75-mm M-349 HEP-T	5.27	4.35
105-mm M-323 HE	5.80	4.75
105-mm M-326 HEP-T	7.50	6.00
106-mm M-346 A1[1] HEP-T	7.60	6.05

[1] Winerack not required. All other ammunition must be in an approved winerack.

Underground Storage—Ammunition may be stored underground, cordwood style, at less than the minimum distances of 800 feet (75 mm) and 1,200 feet (105 and 106 mm), if the following formulas are used to determine the depth of cover for protection against fragment throw:

Hard unfractured rock or concrete: $D = 3W^{0.30}$
Earth, fractured or soft rock: $D = 3.5W^{0.33}$
Where: D = cover thickness in feet and
W = explosive filler weight of TNT in pounds.

HEP-T ammunition has an explosive filler of Comp A3. The filler weight must be multiplied by a factor of 1.35 to obtain the equivalent TNT filler weight. The explosive filler weight W is the sum of the weights of filler in the total number of rounds to be stored in the facility.

The depth of overburden arrived at by using these formulas is considered adequate against debris throw, except in the direction in which the explosion is vented.

The minimum distance from tram and ski lift towers, terminals, inhabited buildings, and other items that could be damaged by shock waves or airblast from an explosion must be considered on an individual basis. Minimum distances shall be determined as described in the interim change to DOD 6055.9, Chapter 9, Quantity—Distance Standards for Underground Storage.

Tables 10.3 through 10.6 give the number of rounds, total pounds of explosives, and amount of cover required to eliminate debris throw for various types of ammunition using hard rock or earth cover. This is adequate to eliminate debris throw, except in the direction of the access door.

Table 10.3—The amount of cover required to eliminate debris throw for 75-mm M-349 HEP-T ammunition.

75-mm M-349 HEP-T, 2.55-lb Comp A3 (TNT equivalent, 3.45 lb)			
Number of rounds	TNT (pounds)	Hard rock (feet)	Earth cover (feet)
100	345	17.32	24.07
200	690	21.32	30.26
300	1,035	24.08	34.59
400	1,380	26.25	38.04
500	1,725	28.06	40.95
600	2,070	29.64	43.48
700	2,415	31.05	45.75
800	2,760	32.31	47.82
900	3,105	33.48	49.71
1,000	3,450	34.55	55.47

Table 10.4—The amount of cover required to eliminate debris throw for 105-mm M-323 HE ammunition.

105-mm M-323 HE (TNT equivalent, 4.61 lb)			
Number of rounds	TNT (pounds)	Hard rock (feet)	Earth cover (feet)
100	461	18.89	26.49
200	922	23.26	33.30
300	1,383	26.26	38.07
400	1,844	28.63	41.86
500	2,305	30.61	45.06
600	2,766	32.34	47.85
700	3,227	33.87	50.35
800	3,688	35.25	52.61
900	4,149	37.69	56.64

Table 10.5—The amount of cover required to eliminate debris throw for 105-mm M-326 HEP-T ammunition.

105-mm M-326 HEP-T, 7.5-lb Comp A3 (TNT equivalent, 10.1 lb)			
Number of rounds	TNT (pounds)	Hard rock (feet)	Earth cover (feet)
100	1,010	23.90	34.32
200	2,020	29.43	43.14
300	3,030	33.23	49.31
400	4,040	36.23	54.22
500	5,050	38.74	58.37
600	6,060	40.91	61.98
700	7,070	42.85	65.22
800	8,080	44.60	68.16
900	9,090	46.21	70.86
1,000	10,100	47.69	73.37

Table 10.6—The amount of cover required to eliminate debris throw for 106-mm M-346 A1 HEP-T ammunition.

106-mm M-346 A1 HEP-T, 7.72-lb Comp A3 (TNT equivalent, 10.4 lb)			
Number of rounds	TNT (pounds)	Hard rock (feet)	Earth cover (feet)
100	1,040	24.22	34.65
200	2,080	29.69	43.55
300	3,120	33.52	49.79
400	4,160	36.55	54.75
500	5,200	39.08	58.93
600	6,240	41.27	62.59
700	7,280	43.23	65.85
800	8,320	44.99	68.82
900	9,360	46.61	71.55
1,000	10,400	48.11	74.08

Weapons Security—Discourage theft of avalanche-control weapons by:

✱ Removing vent assembly, firing pin, breech, or similar part of the weapon after the firing sequence and storing the part in the ammunition storage magazine or other similarly locked facility.

✱ Removing weapons from the firing stand and storing them in a locked facility at the end of the avalanche season.

✱ Securing the weapon to its mount during the firing season.

10.5.8 Avalaunchers

1—Assembling Rounds

A. Gather components to assemble enough rounds for the mission (primers, caps, fin assemblies, nose cones).
B. Prepare the rounds in a controlled environment.
C. Before assembly, count out an equal number of fin assemblies, primers, caps, and nose cones.
D. Round assembly.
   1. Inspect primer for correct cap well depth and diameter, and for pieces of Pentolite in the cap well.
   2. Inspect the fin assembly, making sure all parts are present. Check for any irregularities in final assembly.
   3. Inspect the primer's nose cone for proper seating.
   4. Hold the fin assembly upright and place the cap on the nipple, making sure it seats properly.
   5. Lower the primer over the cap and seat it in the fin assembly. Avoid forcing the primer over the cap.
   6. Transport assembled rounds, if necessary, with caution. Before moving the rounds, package them so they are stable.

2—Tower Procedure

A. Clear snow from the tower and inspect all equipment.
B. Check the range of the swivel on the avalauncher and adjust the braking mechanism used for locking swivels.
C. Quickly release the valve on the nitrogen bottle to be used. Expel a quick blast of gas to ensure a clear opening free of foreign matter. Check the bottle's threads for ice.
D. Inspect the male gas hose coupling for ice and other obstructions.
E. Prime vessel and add gas until flapper valve closes:
   1. Check barrel and assemblies for ice.
   2. Check that match marks on the barrel are in the correct position in relation to loading tray.

3. Check the vessel for gas leaks. If a leak is found, do not fire the avalauncher until the leak is fixed.
4. Test fire unloaded avalauncher at 50 psi.

3—Loading

A. Keep the number of personnel and the amount of ammunition in the area to a minimum.
   1. Single gunner missions are permissible. However, all steps in this procedure shall be followed.

B. Loading
   1. Maintain horizontal position or elevation position.
   2. Check to make sure that the safety valve is in the *on* position.
   3. Prime the vessel until the flapper valve closes (50 psi standard)
   4. Sight the avalauncher to the proper deflection for the desired shot.
   5. Slide the barrel out of the loading tray and lock it into position for loading.
   6. Visually check to make sure the projectile is properly assembled. Place the round in the loading tray, making sure it is properly seated. Remove the cotter pin from the assembly and set it aside to keep track of the number of rounds fired.
   7. Slide the barrel into the loading tray, checking that match marks on the barrel are in the correct position in relation to the loading tray.

4—Firing

A. Registration round
   1. A "safe" first shot must be fired on each mission to indicate if there is any variance in normal weapon behavior.
   2. Shot pressures should be kept above 65 psi to ensure that friction removes the base plate/arming mechanism after the round has left the barrel.
   3. For firing missions involving new platforms, new terrain, or new targets, gunners should gather data by aiming low and gradually work shots into the desired location.

B. Firing
   1. Raise the avalauncher to the proper elevation, if applicable.
   2. Fill the pressure vessel to the desired pressure and double check the pressure with data on the graphs and charts supplied with the avalauncher.
   3. Recheck the deflection and elevation.
   4. The gunner calls out *All clear.*
   5. The gunner calls out *Ready to fire* and releases the safety valve.
   6. The gunner calls out *Fire* and presses the trigger valve to fire.
   7. The gunner observes the projectile flight to note discrepancies in the trajectory and point of impact in case of a dud.
   8. Close the trigger and the safety valve.
   9. Open the pressure valve, priming the system until the flapper valve closes (50 psi).

C. Mission record information
   1. The date and time.
   2. The name of the person who fired the avalauncher.
   3. Pressure, elevation, and results for each shot fired.
   4. Wind and temperature.
   5. All duds and any probable causes.
   6. Any additional comments pertinent to the mission such as maintenance needs.

D. Projectiles with fuses shall be destroyed in place.

10.5.9 Firing Procedures (RESERVED)

10.5.10 Gunnery Training Procedures (RESERVED)

10.6 Fireline Explosives

10.6.1 General

Fireline explosives are linear explosives. Under certain conditions, fireline explosives can enable crews to construct firelines much faster and with less environmental impact than conventional methods. The quality of constructed line varies from a nearly finished line in light brush or grass fuels to line requiring only sawing of heavy brush and slash fuel types. Even in heavy brush and slash, explosives can enhance the effectiveness of fire crews who finish the line.

All fireline explosives are tested by the Bureau of Mines to ensure that they will not accidentally detonate in field conditions. They are impact tested to ensure that they will not detonate when delivered as paracargo, even if the parachute fails to deploy. They will not detonate when shot with a .30-caliber projectile, nor will they mass detonate if they accidentally catch on fire. Only fireline explosives that pass these tests and are accepted on the qualified products list can be used for fireline construction. The EBW system is

used with fireline explosives to ensure the safest system for building firelines. Nonelectric detonating systems may be used for backup.

Attributes of Fireline Explosives—As labor and overhead costs rise, blasting fireline can save time and money. Smaller crews may be able to suppress fires because less cutting and digging are required, particularly in heavy fuels or ground cover. The increased speed of building line can save wildland resources. Sometimes smaller crews equipped with explosives can be delivered to a fire faster than larger, conventionally equipped crews. Other advantages of blasting fireline include:

* Brush and other debris (fuel and slash) are scattered rather than piled next to the finished line.

* Mineral soil in the line is loosened and easy to dig for hotspotting and mopup.

* A fine layer of soil dusts fuels close to the line and acts as a fire retardant.

* Blasting is generally more environmentally sound than using handtools or dozers.

* Fireline explosives can be paracargoed into remote locations.

10.6.2 Fireline Explosives

Fireline explosives are typically a minimum of 80 to 100 feet (24 to 30 m) long, range from 1¼ to 1½ inches (3.18 to 3.81 cm) in diameter, and weigh about 55 to 70 pounds when supplied in a cardboard box. Fireline explosives are made and sold as:

* PETN explosive cord supplied by Ensign-Bickford.

* Watergel supplied by Austin or ETI Companies.

Note: PETN explosive cord is typically more rigid than watergel and does not conform to the ground very well. No end connectors are provided on any of the explosives. Ends are taped together to ensure that the blast propagates from one length of the cord to the next. All fireline explosives are Class 1.1D explosives. Watergel explosives are typically supplied folded in a box with detonating cord their full length.

PETN Explosive Cord—PETN explosive cord contains enough high explosive to effectively blast most fuels. It has enough cooling salts to prevent fire starts. Since the cord is relatively heavy, a balance must be struck between performance and weight.

Two production versions of the explosive cord are available: a seven-strand and a four-strand version (Figure 10.13). The seven-strand cord contains enough explosive to effectively blast fireline in most fuels. The four-strand cord is less powerful, but weighs less and is cheaper by the foot.

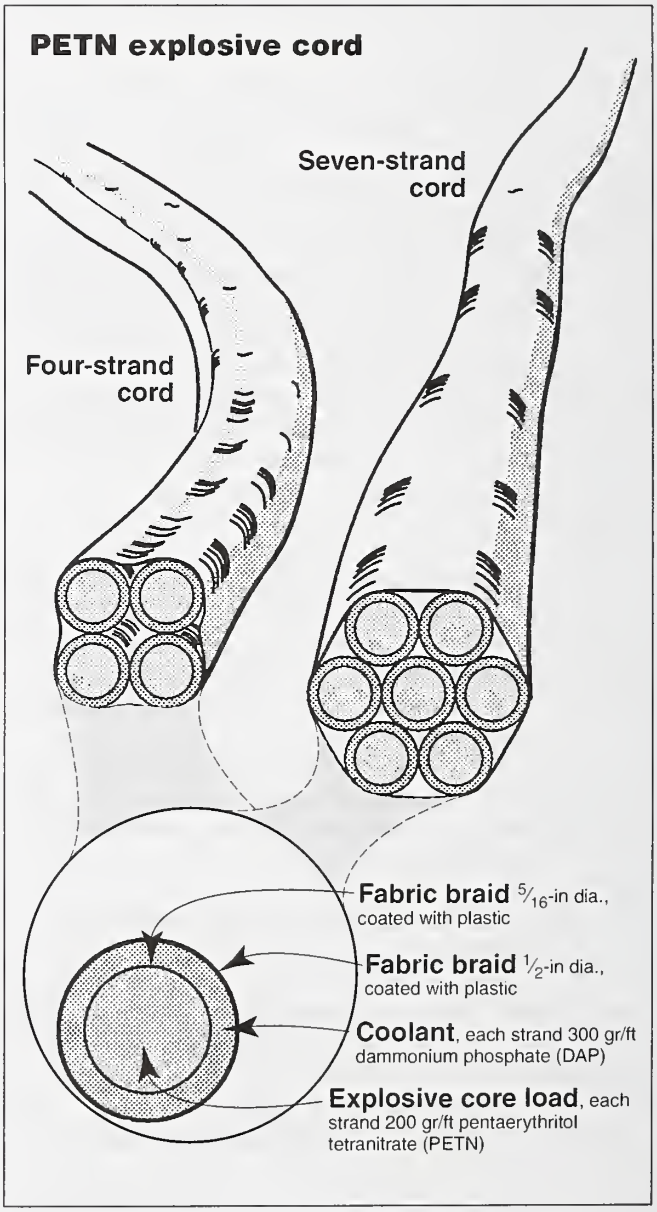


Figure 10.13—Cross-section of PETN fireline explosive cord.

PETN cord detonates at about 21,000 feet per second even at temperatures well below 0 °F.

Both versions of fireline-explosive cord come packaged in a fiberboard box measuring 20¾ by 21½ by 12 inches (54.61 by 52.71 by 30.48 cm). Each box contains about 100 feet (30 m) of the seven-strand cord, weighing about 71 pounds, or 175 feet (53 m) of the four-strand cord, weighing about 70 pounds. PETN has an indefinite shelf life.

Watergel Explosives—Watergel explosives are a slurry-type explosive packaged in plastic tubes 80 feet (15 m) or longer. They are supplied folded in a box with detonating cord their full length. (Figure 10.14).

Figure 10.14—Watergel fireline explosives.

Watergel explosives consist of oxidizing salts, fuels, and sensitizers that are dissolved or dispersed in a continuous liquid phase. The entire system is thickened and made water-resistant by adding gellants and cross-linking agents. The oxidizing salts are usually ammonium nitrate or calcium nitrate. Aluminum, gilsonite, and oil are frequently used as fuels. Chemical sensitizers may include the nitrate salts of organic amines, nitrate esters of alcohols, perchlorate salts, or small particles of aluminum. Entrapped air bubbles may provide physical sensitization, either alone or in combination with chemical sensitizers.

Watergels are Class 1.1D explosives that detonate at a speed of 15,000 to 18,000 feet per second.

Watergels will not detonate consistently at temperatures below 35 °F (4 °C).

The shelf life of watergel is about 18 to 24 months. Some manufacturers report shelf life as long as 5 years.

Emulsions—Emulsions must not be used to construct firelines because they detonate at a temperature high enough to ignite dry fuels. Emulsions may be used to construct trails in areas where moisture content may be high or where temperatures are low (below 32 °F, or 0 °C).

Emulsions are packaged in plastic tubes.

The viscosity of most emulsion formulations changes very little at temperatures down to 10 °F (-12.2 °C). They will typically detonate at temperatures down to 0 °F (18 °C). They do thin out at temperatures above 100 °F (38 °C).

Shelf life and stability of emulsion explosives is excellent, with no change in their explosive properties after 1 year. Storage times can exceed 2 years.

Emulsions are Class 1.1D explosives that detonate at a speed of about 15,000 to 18,000 feet per second.

Safety Tests—The seven-strand fireline cord was originally tested by the Naval Weapons Center at China Lake, CA. The cord was subjected to bullet impact, burning, crushing between caterpillar tread and rocks, chopping with an ax on rock, dragging over rough ground, air dropping 500 to 1,000 feet, bending, and exposure to retardant—all with no indication of possible hazard. Even though safety tests indicate that the cord can be burned without detonating, there is no guarantee that the cord will not detonate.

Watergels (slurries) include some products that are cap-sensitive and some that are not. A significant advantage of watergels is that they are reliably sensitive to conventional priming methods, yet significantly more resistant to accidental detonation from impact, shock, or fire. When subjected to an open flame, watergels will burn, but do not detonate. In a test conducted by the Canadian government, an enclosed truck containing 5 tons of watergel did not detonate when burned. Watergels will not detonate when shot with a bullet from a .30/06 rifle. Watergels are explosives and should be treated with caution. While tests indicate that watergels are relatively safe, severe shocks, such as the impact of higher velocity bullets, can detonate these products.

Emulsions do not use explosive sensitizers. They do not become an explosive until microballoons, or air voids, have been added. Emulsions are perhaps the safest explosives other than watergels in terms of flame, impact, and friction resistance. Emulsions don't detonate during standard impact and friction tests used throughout the industry, including

the bullet impact test. Independent studies to determine the conditions at which explosives detonate show that emulsions have a higher degree of resistance to detonation from impact than either slurries or dynamites. However, emulsions are explosives that are designed to detonate. They demand the respect and proper handling afforded all explosives.

MTDC is responsible for ensuring that all fireline explosives are safety tested. These tests are designed to show that approved fireline explosives meet or exceed the safety characteristics of the seven-strand PETN cord.

10.6.3 EBW Detonators and Firing Sets

The FS-9 Exploding Bridgewire firing system (Figure 10.15) is designed to generate and deliver an electrical energy pulse that will reliably fire EBW's. Electric blasting caps are not used with this system. The FS-9 EBW firing system is recommended for use with fireline explosives. Nonelectric shock-tube-type systems may be used as a backup for initiating fireline explosives (Chapter 3—Detonators and Initiation Systems).

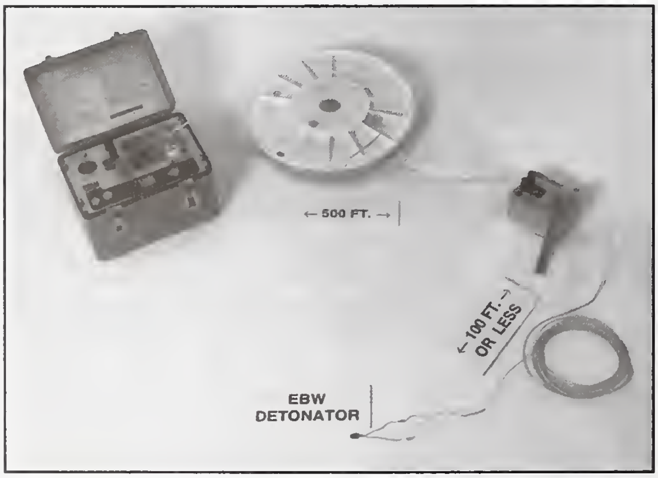


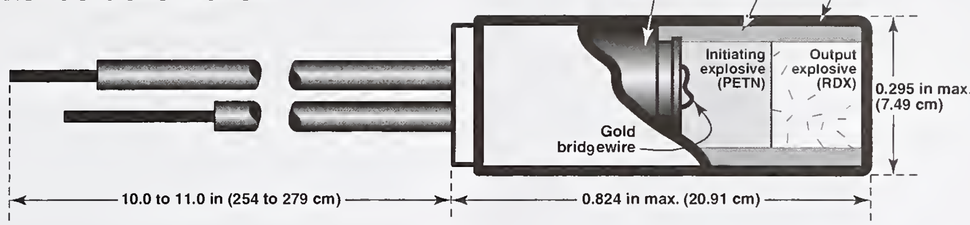
Figure 10.15—FS-9 exploding bridgewire firing system.

EBW Detonators—The EBW detonator (Figure 10.16) is similar in construction to a blasting cap. It contains secondary explosives that will not detonate when exposed to heat, friction, fire, static electricity, low voltages, or radio transmissions. EBW detonators are rated Class C explosives and have less restrictive shipping regulations than conventional blasting caps. EBW's must be stored the same as conventional blasting caps.

Control Units—The FS-9 control unit (Figure 10.17) sends low-voltage electrical energy (40 volts DC) to the firing module and ensures a safe and reliable operating sequence for firing EBW detonators. The energy is sent to the firing module when both the *Hold-to-Arm* and *Hold-to-Fire* buttons are simultaneously pressed and the shunting plug is mated into the control unit's *Safety Interlock* connection. When the *Hold to Arm* button is pressed, the *Battery OK* lamp will illuminate if the batteries are above 32 volts. When the *Hold to Fire* button and the *Hold to Arm* button are pressed, the voltage is applied to the output terminals and the *Ready* lamp illuminates. If the firing module is connected, it will begin arming and automatically fire within 2 to 8 seconds. To abort the firing while arming is taking place, merely release the *Hold to Arm* or *Hold to Fire* button, or both buttons, before detonation occurs. The FS-9 control unit includes:

* A shorting plug that precludes arming the system until the plug is mated to the control unit's *Safety Interlock* connection.
* Dual pushbutton or toggle switches for firing.
* *Ready to Fire* lamp indicator.
* Internal batteries.
* A battery charger that operates from 110-volt AC line voltage.
* A battery check lamp that allows the verification of adequately charged batteries.
* A sealed case for carrying the firing system.
* A fuse to protect the system circuitry.
* Wire screw plugs for wire connections.

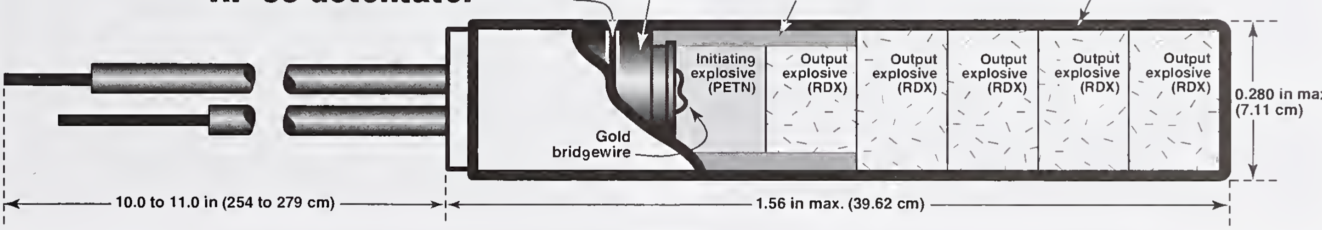
RP-80 detontator



RP-80 parts description

- Molded head: FM #4005 phenolic.
- Brass sleeve.
- Gold bridgewire: 0.0015-in diameter, 0.04-in long.
- Initiating explosive: 80 mg of PETN.
- Output explosive: 123 mg of RDX with binder.
- Cup: 0.007-in-thick aluminum.
- O-ring.

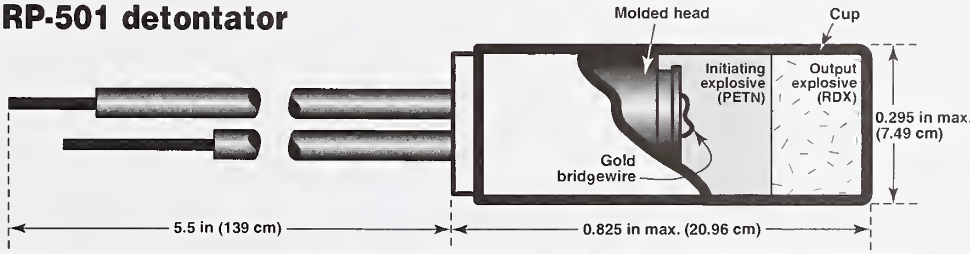
RP-83 detontator



RP-83 parts description

- Molded head: FM #4005 phenolic.
- O-ring.
- Gold bridgewire: gold, 0.0015-in diameter, 0.040-in long.
- Brass sleeve.
- Initiating explosive: 80 mg of PETN.
- Total output charge: 1,031 mg of RDX with binder (13.5 grains) at 1.55- to 1.70-gn/cc density.
- Aluminum cup: 0.007-in-thick aluminum.

RP-501 detontator



RP-501 parts description

- Molded head.
- Gold bridgewire: gold, 0.0015-in diameter, 0.040-in long.
- Initiating explosive: 136 mg of PETN.
- Output explosive: 227 mg of RDX with binder.
- Cup: 0.007-in-thick aluminum.

Figure 10.16—Three types of EBW detonators.

Figure 10.17—FS-9 control unit.

Firing Modules—The firing module (Figure 10.18) is separated from the control unit so the operator can detonate the charge from as far as 500 feet away. The input to the FS-9 module must be between 32 and 40 volts. This input charges a 1-microfarad capacitor. When the energy storage capacitor reaches 3,000 volts, it discharges across the *To EBW Detonator Only* terminals of the firing module. If the shorting plug is mated to the *Discharge* connection, the energy storage

Figure 10.18—FS-9 firing module.

capacitor is completely discharged, precluding inadvertent arming of the firing module and detonation. The firing module consists of a completely sealed metal box that includes:

* Binding posts for connecting the input wires from the control unit.

* A voltage conversion system to increase the input voltage to approximately 3,000 volts to ensure proper functioning of the EBW detonator.

* An automatic trigger system that discharges when the module contains enough energy to fire the detonator (3,000 volts).

* An internal discharge capability in the event of a misfire or abort.

* An external shorting capability across the energy storage capacitor with the same connector or shorting plug used with the control unit's *Safety Interlock* connection.

* Binding posts for connecting the output wires to the detonator.

Lead Wires—Duplex strand solid-core 18- or 20-gauge wires are used as primary and secondary lead wires. The secondary lead wire can be from 500 feet to 2,500 feet long. The primary lead wire can be no more than 100 feet long. The wire should have slick, tough, insulation.

10.6.4 Procedures

Communications—The Blaster-In-Charge will plan communications with a designated blasting team regarding:

* Safety.

* Layout and firing procedures.

* Location of guards and/or flaggers.

* Length of explosive that can be safely guarded and controlled.

The blasting team should have a clear channel of radio communication while blasting. Each team member should have a radio.

The Blaster-in-Charge must brief the team to ensure good communications. Some suggested points to be covered in the briefings are:

* Packers (also typically guards)
  –Discuss various methods of explosive deployment.
  –Do not throw boxes of fireline explosives or handle them roughly.

Before hookup of each fireline segment, the Blaster-in-Charge or the Assistant Blaster will make a final check.

* Guards (also typically packers)
  –Assign each guard a number (Guard 1, Guard 2).
  –Indicate where the guards are to be located and be sure they know their location—a minimum of 500 feet from the firing line (Figures 10.19 and 10.20).

Explosives layout and guard positions

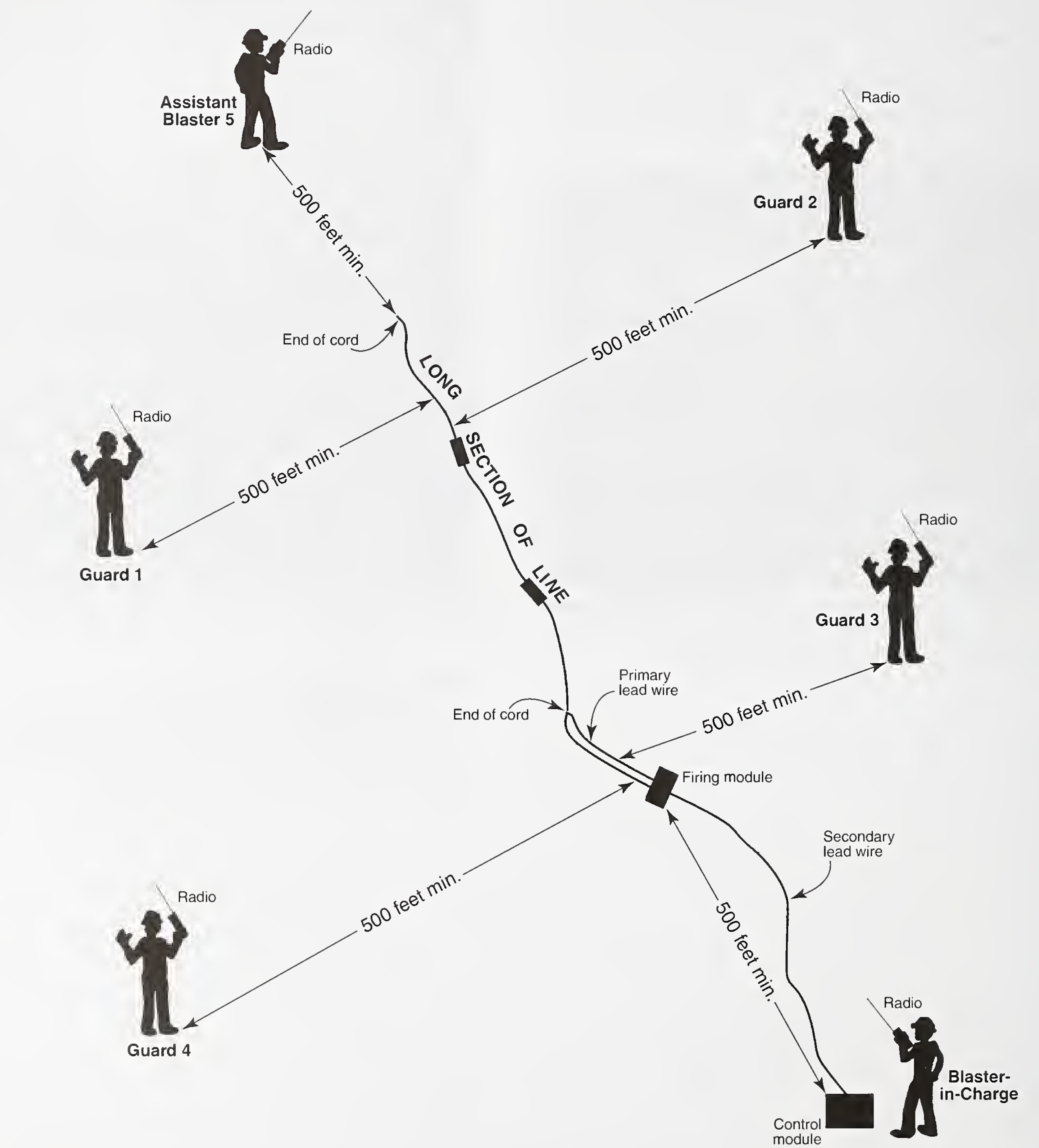


Figure 10.19—Example of explosives layout and placement of guards. Gurads are numbered by the Blaster-in-Charge.

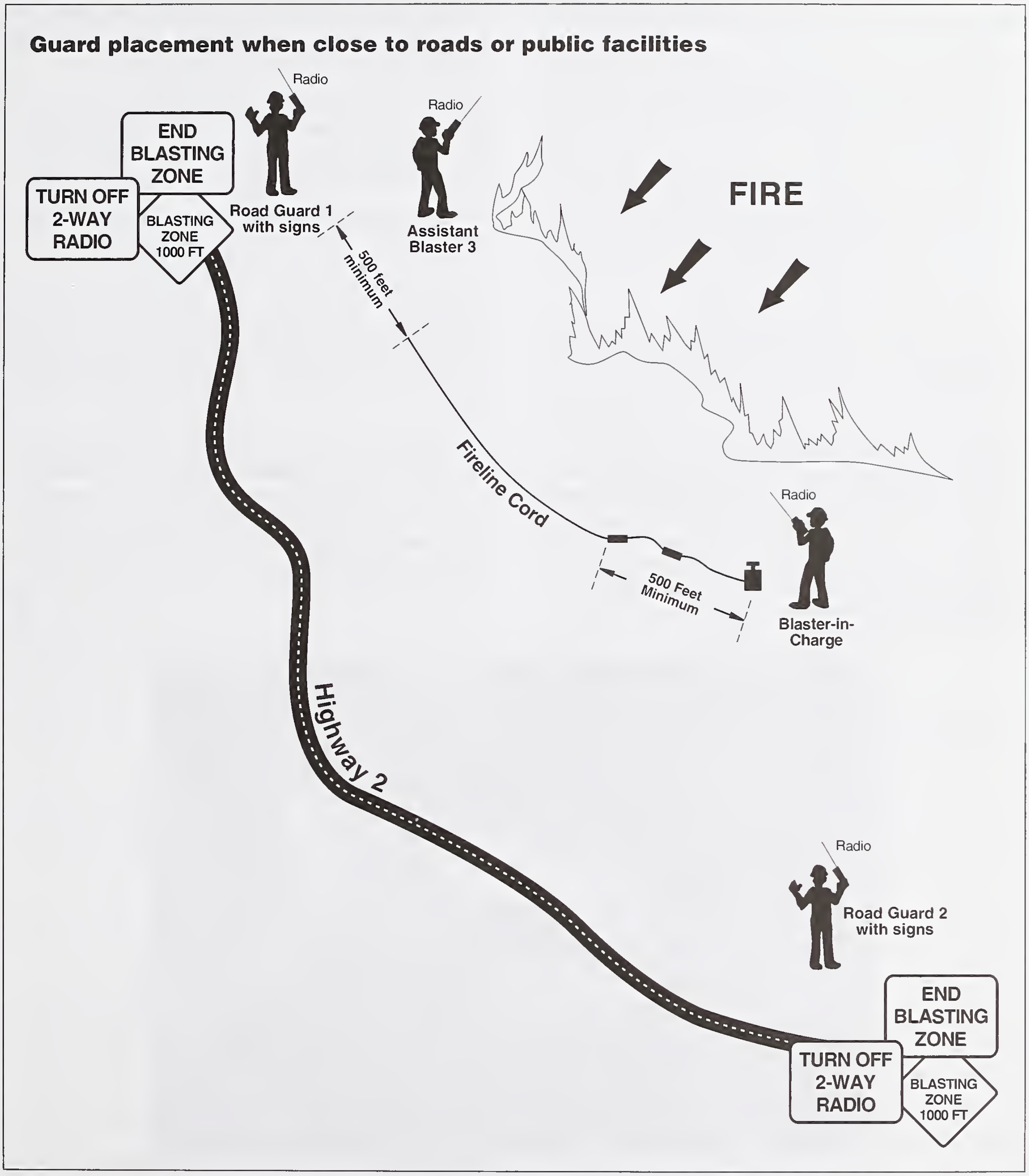


Figure 10.20—Placement of guards when blasting close to roads or any public facility. Guards are numbered by the Blaster-in-Charge.

–Cover radio and verbal communication techniques that will be used, including the number that identifies each guard.
–Guards should have a good vantage point for observing and listening around the blasting area.
–Guards should not stand under snags, in heavy brush areas, or in slide areas.
–Guards should not return to the blasting area until the *All Clear* has been given by the Blaster-in-Charge.
–Guards should watch the horizon for flying objects and use a tree or rock as shelter if necessary.
–Guards must stop the blasting sequence if ***at any time, for any reason*** they deem it unsafe.

Layout Procedures for Fireline Explosives—The Blaster-in-Charge must have all EBW detonators and the control unit under personal control during all blasting operations.

There are two methods of deployment: the carton or reel of explosives can be carried while the end of the cord is stationary, or the carton or reel can be stationary while the cord is pulled from the reel or box. After deployment, the ends of adjacent cords are overlapped 6 to 8 inches and taped together (Figure 10.21). When properly attached, any number of cords can be fired with a single detonator. The number of cord lengths per blast or shot will be determined by the Blaster-in-Charge.

The explosive is most effective when placed on or near the ground and under downfall. Large logs can be wrapped with the explosive, sawed, or left for sawing later.

After the explosives are placed, either the Blaster-in-Charge or the primary assistant should ensure that the fireline explosives are properly positioned and that all joints are securely taped, tied, or clamped together.

The Assistant Blaster should move to a position at least 500 feet beyond the end of the fireline cord. The Blaster-in-Charge must also be at least 500 feet away.

The Assistant Blaster and any guards shall be a minimum of 500 feet from the explosive and guard the area from all intruders from any direction. Guarding the area is critical to the safety of the operation. Inadequate guarding is the most common cause of explosive-related accidents.

The Blaster-in-Charge must positively determine that all guards are properly placed, all other crewmembers are in a safe area, and that the blasting zone is clear of all personnel for at least 500 feet. ***Care should be exercised when selecting safe areas*** *to ensure adequate protection from flying objects, falling rocks, tree limbs, and objects that might ricochet.*

Figure 10.21—Splicing fireline explosives.

Detonator Connection Sequence—Check the continuity of the secondary low-voltage lead wire with the galvanometer. This is done by stripping about 2 inches of insulation from the wire, shorting one end of the lead wire, and touching the other end of the wires to the poles of the galvanometer.

The EBW detonator lead wire need not be shunted during shipping or while performing the hookup procedure.

Check the continuity of the EBW detonator with the galvanometer.

Connect the detonator to the primary (high-voltage) lead wire. This is done by placing a lead wire and a detonator wire parallel to one another, then making a loop.

Check with guards by radio. If it is safe to continue, yell *Blasting one* (first call).

Blasting one, Blasting two, and *Blasting now* **are substituted** for *Fire one, Fire two,* and *Fire in the hole.* These signals are used to prevent confusion on fires.

Attach the detonator to the explosive. This is typically done by inserting the cap into the explosive with the end of the cap pointed in the direction that the explosive was deployed. When using the RP-80 directional detonator and seven-strand detonator cord, place the detonator perpendicular to the fireline explosive. Tape the detonator in place so it cannot be dislodged, or tape it securely to the outside. Be sure that the wire leads do not touch each other or any other materials such as leaves and grass. Move to the firing module.

Firing Module Hookup Sequence—Insert the shunting plug into the module's *Safety Interlock* connection. This creates a short circuit in the system and drains off any electricity that may have built up in the module.

Check the continuity of both primary and secondary lead wires before connecting them to the firing module.

Connect both lead wires to the module. These can be connected backwards, so carefully examine the module. The yellow side reads, *To EBW Detonator ONLY.* The black side reads, *To Control Unit.* Screw-type plugs connect them.

Check with guards by radio. If it is safe to continue, yell, *Blasting two* (second call).

Remove the shorting plug. Check to see that the leads are not shorted.

Move to the control unit. Be sure to take the shunting plug.

Hooking Up the Control Unit—Connect the secondary lead wires coming from the firing module to the FS-9 control unit. Two wire screw plugs are used for the connection.

Check with guards by radio. If all clear, yell *Blasting now* (third and final call).

Insert the shunting plug into the control unit's *Safety Interlock*. The shunting plug ***must*** be plugged in or the system will not work.

Depress the *Hold to arm* button. The *Battery OK* light should illuminate within 2 seconds.

Simultaneously activate the *Hold to arm* and the *Hold to fire* switches. The *Ready* light will illuminate. Detonation will occur within 2 to 8 seconds.

Postfire Procedures—Remove the shunting plug from the control unit's *Safety Interlock* connection. This renders the control unit inoperable.

Call the end guard at the far end of the line. Tell the guard to check that end to see if detonation was complete. ***The end guard is the only other person besides the Blaster-in-Charge that is cleared to enter the blast site at this time.***

Disconnect the lead wires from the control unit terminal marked *To Firing Module*. Short the lead wires together for future electrical continuity checks and move to the firing module. Be sure to take the shunting plug.

Insert the shunting plug into the firing module's *Safety Interlock* connection. This renders the firing module inoperable and bleeds off any excess electricity.

Disconnect the lead wires from the firing module's terminals marked *To Control Unit.*

Disconnect lead wires from the terminals marked *To EBW Detonator Only* and move to the fireline.

Check to make sure all the explosives have detonated and check with the guard at the far end of the line to confirm that all of the explosives detonated at that end.

Radio all guards that it is clear to enter the blasting area.

If the guard on the far end of the line finds undetonated explosives, keep all personnel out of the area and notify the Blaster-in-Charge. The Blaster-in-Charge will walk the line and determine why the explosive did not detonate. If the misfire was caused by an improper connection, attach a new cap to the end of the explosive and detonate it using the procedures previously outlined. If the explosive is burning, clear the area and wait until it has burned out. Before proceeding with a second blast, the end guard will secure the approval of the Blaster-in-Charge and check again to be sure it is clear before allowing the crew to return.

Misfire Procedures—In the case of a misfire, the detonator didn't receive enough energy or the energy pulse had an incorrect rise time or frequency. On rare occasions, a detonator may be faulty. Even if the initial energy pulse does not break the bridgewire, the detonator may not be accidentally detonated. It is safe to handle immediately and is not hazardous in this condition. The only possible hazard is the fireline explosive. Once the Blaster-in-Charge has determined that it is safe to proceed to the explosive, this procedure should be followed:

1—Remove the shunting plug from the control unit's *Safety Interlock* connection.

2—Recheck the batteries and fuse. If the fuse is blown, the wires between the control unit and the module could be shorted. Correct this condition, replace the fuse, and restart the firing procedure.

3—If this is not the case, disconnect the wires at the control unit from the terminals marked *To Firing Module* and shunt them so the continuity can be checked at the firing module.

4—Take the blasting galvanometer and shunting plug to the firing module.

5—Mate the shunting plug into the *Safety Interlock*.

6—Disconnect wires at the firing module from the terminals marked *To Control Unit* and check for continuity. If there is none, determine where the wires are broken and repair or replace them. Then restart the firing procedure.

7—Disconnect wires at the firing module from terminals marked *To EBW Detonator Only* and check for continuity. If continuity does not exist, the electrical pulse did not reach the detonator. Either the lead wires are broken or the detonator is faulty. Shunt the lead wires at the firing module.

8—Return to the detonator. Disconnect the detonator and check the continuity of both the detonator and lead wires. Replace either item if continuity does not exist.

9—If all components appear normal during this procedure, replace the detonator and the primary lead wire from the detonator to the firing module. The most likely cause of a failure is within the twin lead wires because of the high voltage of the firing pulse.

10—An additional check may be done on the primary wire. If the insulation is damaged on the wire from the firing module to the detonator, the firing pulse may arc across these points or to ground, reducing the energy that reaches the bridgewire in the detonator.

It is good practice to check both the short and long lead wires for breaks when coiling them. When setting up, the Blaster can let the wire run through either hand. Breaks in the insulation can often be felt, then repaired or replaced.

Other Considerations—If a portion of the explosives did not detonate and if the explosives are not threatened by fire, cut off any mangled or damaged explosive material and attach it snugly to an undamaged section a foot or more from the cut end. Place a new detonator in the explosive and restart the firing procedure.

If for some reason it is impractical to shoot a failed portion of explosive material, it can be placed in one of the original boxes and returned to the magazine. If this is done, ***be sure to make the person in charge of the magazine aware of it.***

If you have explosives in a vehicle on a return trip, be sure to leave the explosives placards in place.

If you have no explosives other than detonators, placards must be removed from the vehicle before starting the return trip.

Remember to return any remaining explosives, including detonators, to an approved magazine. See that any needed corrections are entered in the magazine inventory.

Maintain a shot log or blasting record showing the date and time of each blast and the amount and type of explosives used. (Chapter 1, Figure 1.8)

10.7 Disposing of Deteriorated or Damaged Explosives

10.7.1 General

A qualified Blaster may destroy a small amount of excess explosives that have not deteriorated. If large amounts of explosives need to be destroyed or if they are old or deteriorated, request assistance from qualified persons, such as local explosive dealers, manufacturers, State police, or military bomb squads.

Destroy only one type of explosive at a time. Select a site where access can be controlled and blasting is acceptable. Detonate explosives in small quantities (maximum of 50 pounds). If there is any question about the condition of the explosives, test fire one cartridge first.

Place explosives in a shallow hole along with a primer made from new explosive. Proceed following standard blasting procedures. Destroy any empty boxes, paper, and fiber packing materials that have previously contained high explosives by burning them at an approved location.

10.7.2 Dynamite

Only nitroglycerin products that are not in a deteriorated condition may be moved to another site for disposal by detonation.

Do not attempt to move or handle any dynamite that is old, shows signs of deterioration, or has visible beading on the surface. Very old dynamite may not show beading on the cartridges, but usually the nitroglycerin has migrated through the bottom or end of the cartridges and is in the container, on the ground, or on the floor. Explosives in this condition are highly unpredictable and are susceptible to detonation from friction or impact.

Do not attempt to move items that are in contact with old dynamite, such as a fiber box or pieces of debris. If these items have nitroglycerin on them, friction from movement may cause detonation. If you cannot safely detonate such explosives, guard the site to protect the public and notify the bomb squad.

10.7.3 Other Explosives

Some explosives, particularly the newer ones, may require disposal techniques other than detonation. For example, a two-component explosive (fertilizer) usually can be deactivated by diluting the mixed explosive with an ample supply of water and spreading it on mineral soil by a road or trail.

Consult the explosives manufacturer for specific disposal practices and recommendations. Explosives manufacturers have agreed to take back explosives that are damaged, unusable, or deteriorated. ***Do not burn*** explosives.

10.7.4 Detonators

Destroy all delay or instant electric blasting caps that are deteriorated from age or improper storage. Such caps may be very dangerous to handle. They should not be disturbed until an experienced Blaster certified for disposal or a technical representative of the manufacturer has an opportunity to check them. As stated earlier, the manufacturer may assume responsibility.

If the caps are excess but are not dangerous to handle, you may destroy them as follows:

1—Separate the detonator from the shunted wire by about one foot. Do not remove the shunt. Keep the rest of the wire coiled as originally packed. Group the detonators so the detonating end of each cap is close to the others (a large rubber band works well to hold them together). Prepare no more than 50 detonators and place them in a hole where they will be confined. Make up an explosive charge and place it in good contact with the detonators. Prime the charge with a good detonator or detonating cord.

2—For nonelectric caps, cut the plastic tubing off close to the cap. Destroy the nonelectric caps in the same manner as electric caps. Burn the tubing.

3—After detonating, thoroughly examine the ground around the shot to be sure no detonators are unexploded.

4—Do not use the same area for successive shots unless the entire area feels cool to the touch.

10.7.5 Detonating Cord

Detonating cord can be disposed of in the same manner as detonators; confine it in a hole, put a charge on top, and detonate it. If the condition of the cord is questionable, consult the manufacturer for assistance.

10.7.6 Ammunition

See 10.5 Avalanche Blasting.

Chapter 11—Ground Vibration and Airblast

11.1 General

Ground vibration and airblast damage may be serious problems for any blasting operation carried out around populated areas, facilities, or structures. The U.S. Bureau of Mines has conducted many studies on ground vibration and airblast in relation to surface mining.

Particle velocity is the best criterion for predicting structural damage due to ground vibrations. In most cases, if blasts are designed to eliminate damaging ground vibrations, the airblast hazard is taken care of. This doesn't apply to surface blasts where airblast is the primary hazard.

A peak particle velocity of 2 inches per second (ips) adjacent to a structure will probably result in little vibration damage (Figure 11.1). Limiting peak velocity to 0.4 ips should minimize complaints from adjacent property owners. The Surface Mining Control and Reclamation Act (P.L. 95.87) limits the maximum particle velocity to 1 ips. This standard shall be followed in Forest Service blasting.

VIBRATION ALLOWANCES
Range of Common Residential Criteria and Effects
(inches per second)

20 ips—For close-in construction blasting, minor damage to nearly all houses; structural damage to some. A few may escape damage entirely. For low-frequency vibrations, major damage to nearly all houses.

9 ips—About 90 percent probability of minor damage from construction or quarry blasting. Structural damage to some houses; depends on vibration, source, character of the vibrations, and the house.

5.4 ips—Minor damage to the average house subjected to quarry blasting vibrations (Bureau of Mines Bulletin 656).

2.0 ips—Widely accepted limit for residences near construction blasting and quarry blasting (Bureau of Mines Bulletin 656, R1 8407, various codes, specifications, and regulations). Also allowed by the Office of Surface Mining (OSM) for frequencies above 30 Hz.

1.0 ips—OSM regulatory limits for residences near surface mine operations at distances of 300 to 5,000 feet for long-term, large-scale blasting.

0.75 ips—Recommended guideline for sheetrock construction near surface mines (R1 8507).

0.5 ips—Recommended guideline for plaster-on-lath construction near surface mines for long-term, large-scale blasting operations (R1 8507).

0.03 ips—Vibrations are detectable to people.

0.0 ips—No vibrations.

Figure 11.1—Ground vibration and airblast damage that would be expected for peak particle velocities of 1 to 20 inches per second.

Usually the distance from the blast area to the nearest structure is fixed.

If you do not have instruments to measure maximum particle velocity, the minimum safe blasting distance is a scaled distance of 60 times the square root of the weight of the explosives charge. The distance in feet (*D*) from the blast to the point of concern divided by the square root of the explosives charge in pounds per delay period of 8 milliseconds or more (*W*) should equal a scaled distance of 60 or more:

$$SD = D/\sqrt{W} > 60$$

For example, if 25 pounds of explosive per delay are being used in a shot and a house is 350 feet away:

$$SD = \frac{350}{\sqrt{25}} > 60 \quad \text{or} \quad \frac{350}{5} = 70 > 60$$

Because 70 is greater than 60, the loading is within the safe limit.

Assume the nearest house is 2,000 feet away. How much explosive per delay can be used safely?

$$SD = D/\sqrt{W} = 60 \quad \text{or} \quad \sqrt{W} = D/60$$

$$\sqrt{W} = 2{,}000/60 \qquad \sqrt{W} = 33.33$$

$$W = 1{,}110 \text{ pounds}$$

Up to 1,110 pounds of explosive can be used per delay.

Assume 36 pounds of explosive is used per delay. How far must the shot be from the nearest house?

$$D = SD\sqrt{W} \qquad D = 60\sqrt{W} \qquad D = 60 \times \sqrt{36} \qquad D = 360$$

The shot must be at least 360 feet from the nearest house.

A shot design uses 10 holes with 40 pounds of explosive in each hole. The nearest house is 720 feet away. How many holes can be shot safely per delay?

$$SD = D\sqrt{W} = 60 \qquad \sqrt{W} = D/60 \qquad \sqrt{W} = 720/60$$

$$\sqrt{W} = 12 \qquad W = 144$$

Up to 144 pounds of explosive can be used per delay. Each hole contains 40 pounds of explosive, so no more than three holes can be shot per delay. At least four delay periods will be needed for this shot.

In areas where complaints are likely, it may be wise to increase the scaled distance to 100 rather than 60. The basic equation in this case would yield values as shown in Table 11.1. It shows allowable weights of explosives per delay at various actual distances for scaled distances of 60 and 100.

Table 11.1—Weight and distance limits for a scaled distance (*SD*) of 60 and 100. The delay must be 8 milliseconds or longer.

Actual distance (feet)	Safe weight of explosives per delay at *SD* 60 (pounds)	Safe weight of explosives per delay at *SD* 100 (pounds)
10	0.03	0.01
25	0.17	0.06
50	0.69	0.25
100	2.78	1.00
250	17.40	6.25
500	69.40	25.00
1,000	277.80	100.00

For large blasts or continuing projects close to any sensitive areas, see U.S. Bureau of Mines Bulletin 656 or consult the Regional Blaster Examiner.

Airblast—Airblast does not cause damage in most ground blasting operations. A safe airblast limit of 0.007 psi overpressure has been recommended in the past (Tables 11.2, 11.3, and 11.4). This equals 128 decibels on the linear peak scale and is the maximum allowed by public law in many locations. However, airblast should be kept below 120 decibels to minimize complaints from the public.

Except in extreme cases such as holes without enough stemming or surface shots, blasting procedures that limit ground vibration levels to 1 inch per second automatically limit overpressure to safe levels. In sensitive areas, airblast can be minimized by eliminating the use of det cord on the surface.

Precautionary measures that will help reduce complaints and damages from airblast include:

* Use adequate burden and stemming (confinement).

* Blast when wind is blowing away from structures and populated areas.

* Avoid blasting during temperature inversions.

* Avoid using detonating cord on the surface (the cord can be covered).

* Blast during period of high ambient noise (noon).

* Reduce pounds per delay in canyons where topography amplifies airblast.

Table 11.2—Typical overpressure criteria.

Overpressure (pounds per sq inch)	Sound pressure level in decibels	Expected results
0.007	128	Safe blast limit; public law
0.0145	134	Okay for large-scale surface mine blasting.
0.029	140	Historical safe project specification.
0.1	151	Occasional window breakage.
1.0	171	General window breakage.
3.0	180	Some structural damage possible.

Table 11.3—Minimum distance to structures to avoid airblast damage.

Amount of explosives to be detonated (lb per delay)	Minimum distance to structures with explosive buried (using "average burial," *SPL*=128 dB, and *SD*=100 feet)	Minimum distance to structures with explosive aboveground (using "blast in air," *SPL*= 128 dB, and *SD*=1,549 feet)
10	215 feet	3,337 feet (0.63 mi.)
50	368 feet	5,706 feet (1.1 mi.)
100	464 feet	7,190 feet (1.4 mi.)
500	794 feet	12,294 feet (2.3 mi.)

This table is based on Table 11.2, using sound pressure level of 128 decibels, and scaled distances of 100 feet for buried detonation and 1,549 feet for surface blasts. This results in maximum allowable overpressure for Forest Service applications as well as limits defined in public law in many locations.

Table 11.4—Minimum distance to structures to avoid airblast damage and minimize complaints from the public.

Amount of explosives to be detonated (lb per delay)	Minimum distance to structures with explosive buried (using "average burial," *SPL*=120 dB, and *SD*=189 feet)	Minimum distance to structures with explosive aboveground (using "blast in air," *SPL*=120 dB, and *SD*=2,600 feet)
10	407 feet	5,601 feet (1.1 mi.)
50	696 feet	9,578 feet (1.8 mi.)
100	877 feet	12,069 feet (2.3 mi.)
500	1,500 feet	20,636 feet (3.9 mi.)

This table is based on Table 11.2, using sound pressure level of 120 decibels, and scaled distances of 189 feet for buried detonation and 2,600 feet for surface blasts, which results in overpressure levels recommended for minimizing complaints from the public.

* Cover drill holes with a layer of sand or dirt or with blast mats to minimize airblast.

Other types of surface blasting may require seismic instrumentation to measure particle velocity and airblast, especially when structures are within 1 mile of the blast site. Tables 11.2 to 11.4 show the minimum distance to structures for different quantities of explosives.

Figure 11.2 shows a series of curves based on the cube root scaled distance in foot pounds to the ⅓ versus sound pressure level (in decibels) or airblast overpressure. Blasts in air, which include surface blasts, will yield higher scaled distances and higher required distance to minimize overpressure. Figure 11.2 should be used to calculate scaled distance and distance requirements for surface blasts and for blasting operations that require more thorough analysis to limit airblast damage. The formula used for airblast is:

$$\text{Scaled distance} = D/\sqrt[3]{W}$$

To limit overpressure to 0.0145 psi (134 dB) from a surface blast of 100 pounds of explosives, the cube root scaled distance from Figure 11.2 would be 1,000 ft per $\sqrt[3]{\text{lb}}$.

This figure is obtained by drawing a horizontal line across the page from 0.0145 psi overpressure to where the line intersects with the *Blasts in air* curve. At this point draw a vertical line to the bottom of the figure to obtain scaled distance. This is approximately 1,000 ft $\sqrt[3]{\text{lb}}$. Solving the above formula for *D*:

$$D = 1{,}000 \times \sqrt[3]{W} \times 100 = 4.6415 \times 1{,}000 = 4{,}641 \text{ feet}$$

Detonating 100 pounds of explosives on the surface would require a minimum distance of 4,641 feet (just under a mile) to minimize overpressure to 0.0145 psi. Using a more conservative number of 0.007 psi for residences or sensitive structures yields a scaled distance of 2,000 ft $\sqrt[3]{\text{lb}}$, doubling the distance to 9,283 feet (almost 2 miles).

What would be the largest quantity of explosives that could be detonated in one shot on the surface 3,000 feet from a residence if the overpressure should be constrained to 0.007 psi?

$$W = (3{,}000/2{,}000)^3 \qquad W = 3.375 \text{ pounds}$$

See other examples in Tables 11.3 and 11.4.

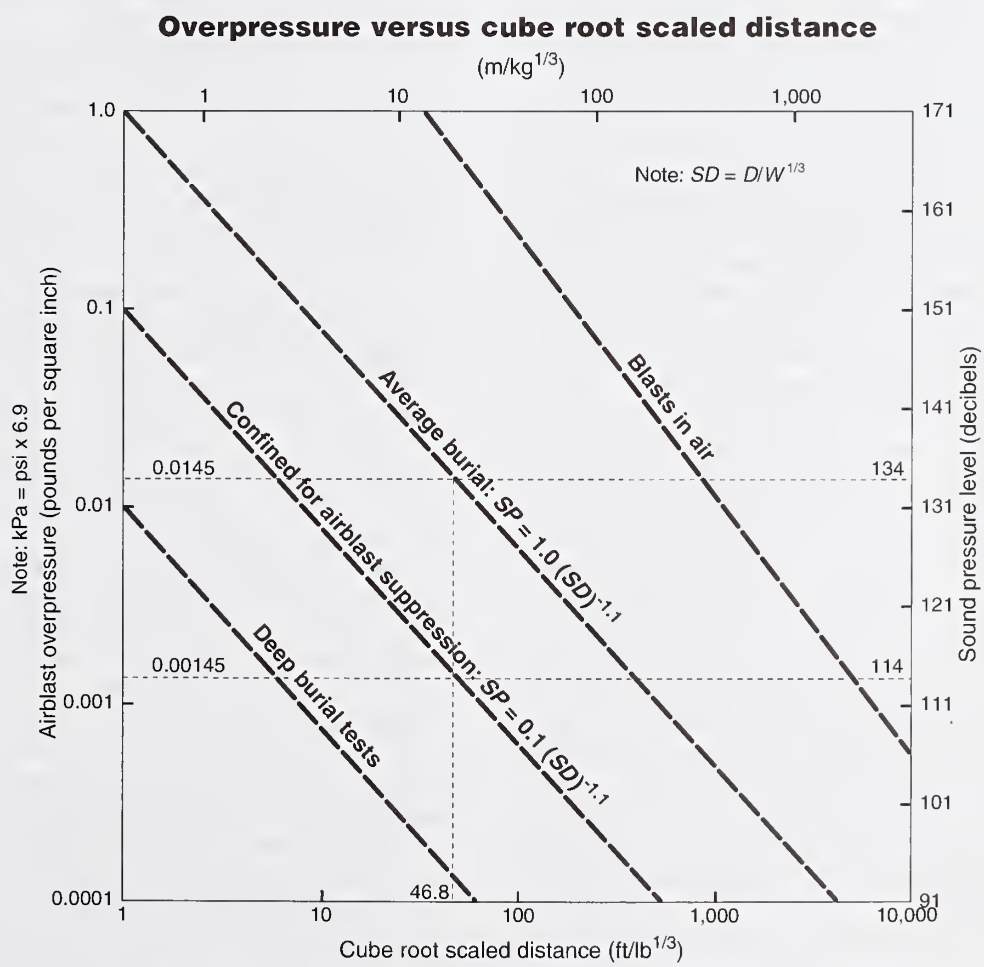


Figure 11.2—Overpressure versus cube root scaled distance.

Definitions

Airblast—The compressional wave in air created by an explosion. Also referred to as overpressure.

Air Gap—A blasting technique in which a charge is suspended in a borehole, and the hole is tightly stemmed to allow a time lapse between detonation and ultimate failure of the rock (no coupling realized).

Ammonium Nitrate—The most commonly used oxidizer in explosives and blasting agents.

ANFO (Ammonium Nitrate Fuel Oil)—A blasting agent that consists of ammonium nitrate prills and fuel oil.

Approved Explosives—Explosives approved by Regional Forester for Regional use.

Approved Storage Facility (Approved Magazine)—A facility for the storage of explosive materials conforming to the requirements in Title 27 CFR, Part 55, Explosive Materials Regulations, Subpart K, Storage; Bureau of Alcohol, Tobacco, and Firearms (BATF).

Back Break—Rock broken beyond the limits of the last row of blast holes.

Bench—A horizontal ledge in a quarry face along which holes are drilled vertically. When benching is used during excavation, terraces or ledges are worked in steps.

Blasting Agent—Any unconfined material or mixture of fuel and oxidizer used for blasting, not otherwise defined as an explosive, that cannot be detonated with a No. 8 test blasting cap. A mixture of ammonium nitrate and fuel oil (ANFO) is commonly used as a blasting agent. Use only premixed and packaged blasting agents from explosives companies or two-component Kinepack or Kinestick.

Blasting Galvanometer—An electrical resistance instrument designed specifically for testing electric detonators and circuits containing detonators. Along with Blasters' ohmmeters, blasting galvanometers are used to measure resistance or check electrical continuity.

Block Hole—A hole drilled in a boulder. A small charge placed in the hole can break the boulder.

Booster—An explosive charge, usually of high velocity and density, used to improve the initiation of less sensitive explosive materials.

Bootleg—The portion of a borehole that remains relatively intact after being charged with explosive and fired (the blast fails to break the material).

Borehole—A hole drilled in rock or other material for placement of explosives. Also known as blasthole.

Bridgewire—A very fine filament embedded in the ignition element of an electric blasting cap. An electric current heats the filament, igniting the ignition element.

Bridging—Where a column of explosives in a borehole is broken, either by improper placement or, as in the case of slurries or poured blasting agents, where foreign matter has plugged the hole.

Bulk Strength—The strength of a cartridge of explosive or blasting agents in relation to a cartridge of straight nitroglycerin dynamite of the same size.

Burden—The distance from an explosive charge to the nearest free or open face. Technically, there may be an apparent burden and a true burden. The true burden is always measured in the direction broken rock will be displaced after firing.

Bus Wire—Solid-core 10-, 12-, or 14-gauge uninsulated copper wire.

Cap Sensitivity—The sensitivity of an explosive to initiation expressed in terms of an IME No. 8 test detonator.

Cartridge Strength—A rating that compares a given volume of explosive with an equivalent volume of straight nitroglycerin dynamite, expressed as a percentage.

Cast Booster—A cast unit of explosive, usually pentolite or Composition B, commonly used to initiate detonation in a blasting agent.

Charge—Explosive load in a hole.

Collar—A borehole mouth or opening. To collar means the act of starting a borehole.

Column Charge—A long, continuous charge of explosive or blasting agent in a borehole.

Condenser Discharge Blasting Machine—Blasting machine that uses batteries or a generator to energize a series of condensers that release stored energy into a blasting circuit.

Connecting Wire—Any wire in a blasting circuit that connects leg wires with lead wire.

Coupling—The degree to which an explosive fills the borehole. Bulkloaded explosives are completely coupled. Untamped cartridges are uncoupled. Coupling can also mean an intimate contact between explosives and rock.

Critical Diameter—The minimum diameter of explosive for propagation of a detonation wave at a stable velocity. Critical diameter is affected by conditions of confinement, temperature, and pressure on the explosive.

Cutoff—When a column of explosives fails to detonate due to bridging or shifting of the rock formation caused by an improper delay system.

Dead Pressing—Desensitization of an explosive caused by pressurization. Pressure squeezes tiny air bubbles, required for sensitivity, from the mixture.

Deck—An explosive charge separated from the main charge by stemming or an air cushion.

Deflagration—An explosive reaction such as a rapid combustion that moves through an explosive material at a velocity less than the speed of sound in the material.

Delay Blasting—The use of delay detonators or connectors that cause separate charges to detonate at different times.

Delay Element—That portion of a blasting cap causing a delay between the instant electrical energy is applied to the cap, and the time the cap's base charge detonates.

Density—The mass of an explosive per unit volume, usually expressed in grams per cubic centimeter.

Detonating Cord—A flexible cord containing a center core of high explosives, used to initiate other explosives.

Detonation—An explosive reaction or shock wave that moves through an explosive material faster than the speed of sound in the material.

Detonation Pressure—The pressure produced in the reaction zone of a detonating explosive.

Detonation Velocity—The velocity at which a detonation progresses through an explosive.

Detonator—Any device containing any initiating or primary explosive that is used for initiating detonation. A detonator may not contain more than 10 grams of total explosives by weight, excluding ignition or delay charges. The term includes, but is not limited to, electric blasting caps (instantaneous and delay types), exploding bridgewire, blasting caps for use with safety fuses, delay blasting caps that use connectors, and nonelectric instantaneous and delay blasting caps that use detonating cord, shock tube, or any other replacement for electric leg wires.

Dynamite—A high explosive used for blasting, usually consisting of a mixture of nitroglycerin, nitrocellulose, ammonium nitrate, and carbonaceous materials.

Emulsion—An explosive material containing substantial amounts of oxidizers dissolved in water droplets and surrounded by an immiscible fuel.

Explosion—Thermochemical process in which mixtures of gases, solids, or liquids react with the almost instantaneous formation of gaseous pressures and the sudden release of heat.

Extraneous Electricity—Electrical energy at a blast site, other than the firing current or the test current from a blasting galvanometer, that could enter an electric blasting circuit. Extraneous electricity includes stray current, static electricity, radio-frequency (electromagnetic) waves, and time-varying electric and magnetic fields.

Firing Line—A duplex electric wire (lead wire) or shock tube that carries an electric current or shock wave to initiate a blast. The firing line extends from the point of initiation to the blast area.

Flyrock—Rocks propelled from the blast area by the force of an explosion.

Gap Sensitivity—A measure of the distance across which an explosive can propagate a detonation. The gap may be air or a defined solid material. Gap sensitivity is a measure of the likelihood of sympathetic propagation.

Ground Vibration—Shaking of the ground caused by the elastic wave from a blast. Excessive vibrations may cause damage to structures.

Hangfire—The detonation of an explosive charge after its intended firing time. A source of serious accidents.

Initiation—Detonating a high explosive by a mechanical device or other means.

Lead Wire—The wires connecting the electrodes of an electric blasting machine with the final leg wires of a blasting circuit.

Low Explosives—Explosive materials that are not bullet-sensitive, but that can be deflagrated when confined. For example, safety fuses, igniters, igniter cords, fuse lighters, and special fireworks, formerly defined as Class B explosives by Department of Transportation regulations in 49 CFR, part 173.88(d).

Mass Detonate—Explosive materials mass detonate (mass explode) when a unit or any part of a larger quantity of explosive material explodes and causes all or a substantial part of the remaining material to detonate or explode simultaneously. With respect to detonators, a "substantial part" means 90 percent or more.

Mat—Material used to reduce flying debris during a shot, usually made of woven wire, cable, rope, or linked tires.

Millisecond Delay—Caps Electric caps that have a built-in delay element, usually 0.025 second apart, consecutively (timing may vary with manufacturer).

Misfire—A blast that fails to detonate completely after an attempt at initiation. The explosive material itself may fail to detonate as planned.

Muck Pile—The pile of blasted and broken rock or dirt that needs to be loaded or removed after the shot.

Mud Capping—Blasting boulders by placing a quantity of explosives against a rock, usually on top of a boulder or other object and covering the explosives with clay or mud. Also known as bulldozing, adobe blasting, or dobying.

Overbreak—Rock broken beyond the desired excavation limit.

Overburden—Material lying on top of the rock to be shot; usually refers to dirt and gravel, but can mean another type of rock, such as shale over limestone.

Oxidizer—An ingredient in an explosive or blasting agent that supplies oxygen to combine with the fuel, forming gaseous or solid products of detonation. Ammonium nitrate is the most common oxidizer in commercial explosives.

PETN (PentaErythritolTetraNitrate)—A military explosive compound used as the core load of detonating cord and the base charge of blasting caps.

Powder—A synonym for explosive material.

Powder Factor—The amount of explosive used per unit of rock, expressed as pounds of explosives per cubic yard of rock.

Premature Detonation—Charge detonates before it is intended to.

Presplitting—Stress relief produced by a single row of holes drilled along an excavation line. Pre-split holes are fired in advance of the production blasts; this is done to keep the highwall smooth.

Prills—In blasting, a small porous sphere of ammonium nitrate capable of absorbing more than 6 percent by weight of fuel oil. Blasting prills have a bulk density of 0.80 to 0.85 grams per cubic centimeter.

Primer—A unit, package, or cartridge of explosives used to initiate other explosives or blasting agents that contains a detonator or detonating cord attached to a detonator designed to initiate the detonating cord.

Propagation—The detonation of explosive charges by an impulse from a nearby explosive charge (sympathetic detonation).

Resistance—The difficulty in causing current to flow in an electrical circuit (measured in ohms).

Sensitizer—The ingredient used in explosive compounds to ease initiation or propagation of the reactions.

Series Circuit—An electric blasting circuit that provides one continuous path for the current through all caps in the circuit.

Series Parallel Circuit—An electric blasting circuit in which the ends of two or more series of electric detonators are connected across the firing line directly or through bus wire.

Shunt—Shorting together the free ends of electric detonator leg wires or the wire ends of an electric blasting circuit or part of an electric blasting circuit. The name of an electrical shorting device applied to the free ends of electric detonators.

Spacing—The distance between boreholes or charges in a row.

Specific Gravity—The density of a material compared to water, or the ratio in weight of one volume of material compared to the same volume of another material.

Static Electricity—Electric charge at rest on a person or object that can discharge across an air gap. The contact and separation of dissimilar insulating materials commonly produces static electricity.

Stemming—Inert material, such as drill cuttings, put in the collar (or elsewhere) of a borehole to confine the gaseous products formed by the explosion. Also, the length of borehole left uncharged.

Stray Current—A flow of electricity outside an insulated conductor system.

Subdrill—The portion of the borehole that is drilled and loaded below design grade to ensure that rock will be broken at grade.

Sympathetic Detonation—The detonation of an explosive material as the result of an impulse from another detonation through air, earth, or water.

Tamping—Compressing the stemming or explosive in a borehole.

Toe—In bench blasting, the distance from the free face to the blasthole measured at the floor level of the bench.

VOD (Velocity of Detonation)—The speed at which an explosive changes from a solid state to a gaseous state.

VOS (Sonic Velocity)—The speed at which an acoustical (shock) wave travels through a homogeneous rock mass.

Watergel—An explosive material containing substantial portions of water, oxidizers, and fuel, plus a cross-linking agent.

Explosive Materials

- Any chemical compound, mixture, or device that functions by the instantaneous release of gas and heat, unless the compound, mixture, or device is otherwise specifically classified by the Department of Transportation (DOT).
- DOT classifies explosives as Division 1.1, 1.2, 1.3, 1.5, 1.6 with Compatibility Groups A, B, C, D, E, F, G, H, J, K, L, N, and S. The DOT has developed tables using Division Classification Codes and Compatibility Groups, producing 35 possible classification codes.

Division 1.1—Explosives that have a mass explosion hazard. A mass explosion is one that affects almost the entire load instantaneously.

Division 1.2—Explosives that have a projection hazard but not a mass explosion hazard.

Division 1.3—Explosives with predominantly a fire hazard, and either a minor blast hazard, or a minor projection hazard, or both, but not a mass explosion hazard.

Division 1—Explosives with a minor explosive hazard. The explosive effects are largely confined to the package and no projection of fragments of appreciable size or range is to be expected.

Division 1.5—Very insensitive explosives.

Division 1.6—Extremely insensitive detonating substances.

Compatibility Group A—Primary explosive.

Compatibility Group B—Primary explosive and not containing two or more effective protective features.

Compatibility Group C—Propellant explosive substance or other deflagrating explosive substance.

Compatibility Group D—Secondary detonating substance or black powder, in each case without means of initiation and without a propelling charge or article containing a primary explosive substance and containing two or more effective protective features.

Compatibility Group E—Secondary detonating explosive substance, without means of initiation, with a propelling charge.

Compatibility Group F—Secondary detonating explosive substance, with its means of initiation, with a propelling charge.

Compatibility Group G—Pyrotechnic substance or article containing a pyrotechnic substance, or article containing both an explosive substance and an illuminating, incendiary, tear-producing or smoke-producing substance.

Compatibility Group H—Article containing both an explosive substance and white phosphorus.

Compatibility Group J—Article containing both an explosive substance and a flammable liquid or gel.

Compatibility Group K—Article containing both an explosive substance and a toxic chemical agent.

Compatibility Group L—Explosive substance or article containing an explosive substance and presenting a special risk, needing isolation of each type explosive.

Compatibility Group N—Articles containing only extremely insensitive detonating substances.

Compatibility Group S—Substance or article so packed or designed that any hazardous effects arising from accidental functioning are limited to the extent that they do not significantly hinder or prohibit firefighting or other emergency response efforts in the immediate vicinity of the package.

References

The following materials should be accessible to all Blasters and Blaster Examiners.

* USDA Forest Service Manual: **6700 Safety and Health Program, 6740 Hazardous Materials, 6745 Explosives and Blasting Materials**
  - 6745.01 Authority
    - (a) Use
    - (b) Storage
    - (c) Transportation
    - (d) Disposal
  - 6745.02 Objectives
  - 6745.03 Policy
  - 6745.04 Responsibilities
  - 6745.1 Certification
  - 6745.2 General Standards
  - 6745.3 Contractor Requirements

* **Federal Laws and Regulations** controlling transportation, storage, and use of explosives are listed below. The regulations that most commonly apply to Forest Service activities include:

Title 27, Code of Federal Regulations, Part 55, Storage

Title 29, Code of Federal Regulations
Section 1910.109, Explosives and Blasting Agents
Part 1926, Subpart U, Blasting and the Use of Explosives

Title 30 Code of Federal Regulations
Part 56, Subpart E, Explosives
Part 57, Subpart E, Explosives

Title 33, Code of Federal Regulations
Part 125, Identification Credential for Persons Requiring Access to Waterfront Facilities or Vessels
Part 126, Handling of Class 1 (Explosive) Materials or Other Dangerous Cargoes Within or Contiguous to Waterfront Facilities

Title 36, Code of Federal Regulations, Section 228.8, Requirements for Environmental Protection, requires the removal or control of waste from activities undertaken pursuant to the U.S. Mining Law (Public Domain Lands) Act of May 10, 1872 (Title 30, United States Code, sections 22, 28, 28b; and 30 U.S.C. 22, 28, 28b).

Title 40, Code of Federal Regulations, Part 264, Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities

Title 49, Code of Federal Regulations
Part 172, Hazardous Materials Table, Special Provisions, Hazardous Materials Communications, Emergency Response Information, and Training Requirements
Part 173, Shippers-General Requirements for Shipments and Packagings
Part 174, Carriage by Rail
Part 175, Carriage by Aircraft
Part 176, Carriage by Vessel
Part 177, Carriage by Public Highway
Part 390, Federal Motor Carrier Safety Regulations; General
Part 391, Qualifications of Drivers
Part 392, Driving of Commercial Motor Vehicles
Part 393, Parts and Accessories Necessary for Safe Operation
Part 395, Hours of Service of Drivers
Part 396, Inspection, Repair, and Maintenance
Part 397, Transportation of Hazardous Materials; Driving and Parking Rules

* **USDI Department of Transportation Exemption**
Exemption number DOT-E 9198 authorizes the U.S. Department of the Interior and U.S. Department of Agriculture, Forest Service, to transport hazardous materials in aircraft under their exclusive direction and control. The following regulations and laws do not directly address explosives and blasting materials, but include sections and requirements that directly affect explosives and blasting operations.

* **The Occupational Safety and Health Act** (OSHA; Title 29, United States Code, section 651 et seq.; 29 U.S.C. 651 et seq.) ensures safe and healthful working conditions by encouraging efforts to reduce hazards, set mandatory standards, require training programs, and require medical surveillance programs for hazardous materials. Implementing regulations are in 29 CFR 1960, Basic Program Elements for Federal Employee OSHA Programs; 29 CFR 1910, General Industry; and 29 CFR 1926, Construction.

* **The Comprehensive Environmental Response, Compensation, and Liability Act of 1980** (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA), the Emergency Planning and Community Right-to-Know Act (EPCRA), and the Community Environmental Response Facilitation Act (CERFA; Title 42, United States Code, section 9601 et seq.) and as otherwise amended.

* **The Resource Conservation and Recovery Act** (RCRA) as amended by the Hazardous and Solid Waste Amendments (HSWA), and Federal Facilities Compliance Act (FFCA; Title 42 United States Code, section 6901 et seq.), promotes conservation of valuable material and energy resources; promulgates guidelines for solid waste management; establishes a regulatory system to track hazardous waste from the time of generation to disposal; regulates use of underground storage tanks; phases out land disposal of hazardous waste; and waives sovereign immunity for the United States making Federal facilities subject to civil penalties and fines from the Environmental Protection Agency, State, and local environmental agencies.

* **Executive Order 12856** (E.O. 12856) Federal Compliance with Right-to-Know Laws and Pollution Prevention Requirements (issued August 3, 1993), requires Federal agencies to comply with the Emergency Planning and Community Right-to-Know Act and the Pollution Prevention Act.

* **Guidance on Compliance With Executive Order 12856** (FSM 2160.1, para. 13) including compliance with the Emergency Response and Community Right-to-Know Act (40 CFR 355, 370, and 372).

* **The Federal Tort Claims Act**, as amended in 1988 (Title 28, United States Code, section 2679), protects Federal employees from suit for alleged torts committed within the scope of their duties.

* **State Laws and Regulations**

Blasters' Handbook. 17th edition. International Society of Explosives Engineers, Cleveland, OH.

Handbook of Electric Blasting, 1976. Revised by Atlas Chemical Industries, Explosives Division, Wilmington, DE 1989.

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Avalanche Handbook, Agriculture Handbook 489, July 1976 (slightly revised Nov. 1978). Alpine Snow and Avalanche Research Project, Rocky Mountain Experiment Station, USDA Forest Service, Fort Collins, CO (out of print, but commonly used).

Institute of Makers of Explosives Publications, Nos. 1, 2, 3, 4, 12, 14, 17, 20, 21, and 22, and Guide for the Use of IME 22 Container, 4230 Lexington Ave., New York, NY 10017.

Can Static Electricity From Clothing Detonate Electric Blasting Caps? 1971. Tech Tip 7167-0005-MTDC. USDA Forest Service, Missoula Technology and Development Center, Building 1, Fort Missoula, Missoula, MT 59804.

Blasting Near High Voltage Powerlines, 1974. Atlas Powder Co., Southland Center, Dallas, TX 75203.

National Fire Protection Association Standard No. 78. Batterymarch Park, Quincy, MA 02269.

Blasting Techniques: 1. Estimating the Blasting Project, 1985. Albert E. Teller, P.O. Box 664, Issaquah, WA 98027.

Blasting Techniques: 2. Ditches-Stumps-Boulders, 1983. Albert E. Teller, P.O. Box 664, Issaquah, WA 98027.

Unified Rock Classification System. Douglas Williamson, Engineering Geologist, USDA Forest Service, Pacific Northwest Region, P.O. Box 3623, Portland, OR 97208.

Explosives and Rock Blasting, 1987. Atlas Powder Co., 15301 Dallas Parkway, Suite 1200, Dallas, TX 75248.

Drivers Pocket Guide to Hazardous Materials, 1997. J.J. Keller & Associates, Inc., Sixth Edition, P.O. Box 368, Neenah, WI 54957-0368.

About the Author

Jim Tour is a Project Engineer at MTDC specializing in explosives and incendiaries. Jim began working for the Forest Service in 1970, spending 8 years as a technician at the Technology and Development Center in San Dimas, CA. He received his degree in mechanical engineering at California Polytechnic University Pomona, and came to MTDC shortly afterward. Jim has helped develop incendiary devices such as the Premo MK III aerial ignition device and has helped redesign the helitorch.

Library Card

Tour, Jim. 2000. Guide for using, storing, and transporting explosives and blasting materials: 2000 edition. Missoula, MT: U.S. Department of Agriculture, Forest Service, Missoula Technology and Development Center. 138 p.

This guide for Forest Service Blasters and Blaster Examiners updates the *Guide for Using, Storing, and Transporting Explosives and Blasting Materials* published by the Missoula Technology and Development Center in 1992. The guide presents the minimum requirements for using, storing, and transporting explosives and blasting materials. Chapters cover: general requirements, explosives, detonators and initiation systems, storage, transportation, blasting procedures, geological effects on blasting, blast design, specialty blasting, and ground vibration and airblast. A glossary of terms is included.

Keywords: airblast, detonators, explosive hazard, geology, initiators, safety, safety devices, storage, transport, transportation

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